Sugar-Beet Culture

Under Irrigation in the Northern Great Plains

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Sugar-beet practices that have been found successful in the northern portion of the Great Plains region are outlined in this bulletin. The experimental work on which these practices are based has been conducted chiefly in the irrigated districts of Nebraska, South Dakota, and Wyoming. With proper allowance for local differences in conditions, the methods of sugar-beet culture as here discussed also apply to other areas where sugar beets are grown under irrigation.

The sugar beet has marked adaptability to climatic and soil conditions. If supplied with adequate water, the plant makes satisfactory growth throughout the entire region and over a considerable range of soil types. The crop can be grown on any of the better types of soil. The light to medium sandy loams seem best adapted to sugar-beet culture because they are easily handled, are least subject to serious crusting, and, with proper attention to leveling, are readily irrigated. The heavier types of soil are also suitable for sugar-beet culture, but the successful handling of them presents more problems.

The methods to be followed in growing the sugar-beet crop are greatly influenced by the climate and soil relationships that exist in this region. Thus, in soil preparation, soil erosion and loss of soil moisture by high winds must be avoided. Irrigation practice must take into consideration the rainfall conditions likely to prevail in any given district; for example, furrowing at planting time is advised so that an irrigation to germinate the seed may be given if early precipitation is below normal.

Crop rotations suitable for the region are discussed.

Livestock manures have been found to be very important in obtaining high yields of sugar beets and in maintaining soil fertility. However, until the number of farm animals is increased, livestock manures will need to be supplemented by green manures and commercial fertilizers.

Methods of green manuring as practiced in this region are given. The largest amounts of green manure are obtained if the legume is not plowed under until fairly late in the spring.

In many districts, commercial fertilizers are used with sugar beets. The principal fertilizer material found necessary in soils in this general area has been phosphate, the common rate of application where it is employed being 100 to 200 pounds of treble superphosphate per acre. Possibilities have been shown for combining applications of manure and phosphate.

Recommendations are given for the various operations involved in the production of the sugar-beet crop.

Utilization of sugar-beet byproducts, beet tops, beet pulp, and molasses, for feeding livestock is briefly discussed. For fuller account Farmers' Bulletin 1718, Important Sugar-Beet Byproducts and their Utilization, should be obtained.

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SUGAR-BEET CULTURE UNDER IRRIGATION IN THE NORTHERN GREAT PLAINS

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Contents

INTRODUCTION

THE METHODS of growing sugar beets in the irrigated districts of Nebraska, Wyoming, and South Dakota (fig. 1) are described in this bulletin. The problems with which the average grower is confronted in producing the sugar-beet crop are discussed in nontechnical manner. From beet-sugar factory records, successful farm experience, and applicable experimental data, an attempt is made to outline improved practices for this region. Agronomic experiments[1] conducted from 1930 to 1938 at the United States Scotts Bluff Field Station, Mitchell, Nebr., the United States Belle Fourche Field Station, Newell, S. Dak., and at Torrington, Wyo., have served in large measure to evaluate these methods. The information given may also have applicability to other western areas where conditions for growing sugar beets are somewhat similar.

[1] The agronomic investigations in western Nebraska have been conducted to a large extent at the United States Scotts Bluff Field Station, Mitchell, Nebr., in cooperation with the Division of Irrigation Agriculture; the tests at Belle Fourche, S. Dak., have been in cooperation with the Utah-Idaho Sugar Co.; those at Torrington, Wyo., have been in cooperation with the Holly Sugar Corporation and the University of Wyoming substation.

The average yield of sugar beets in these districts of the northern Great Plains varies from 12 to 14 tons per acre for the different seasons, but the yield for individual growers in almost any district may range from a few tons to over 20 tons per acre. Successful growers make a profit over and above land and labor costs. Many of the less successful operators could make a profit or increase their returns by closer adherence to improved practices. It is the general experience throughout the region that the higher yields produce beets at a lower cost per ton. In this presentation of practices, high yields per acre with the maintenance of soil fertility are stressed.

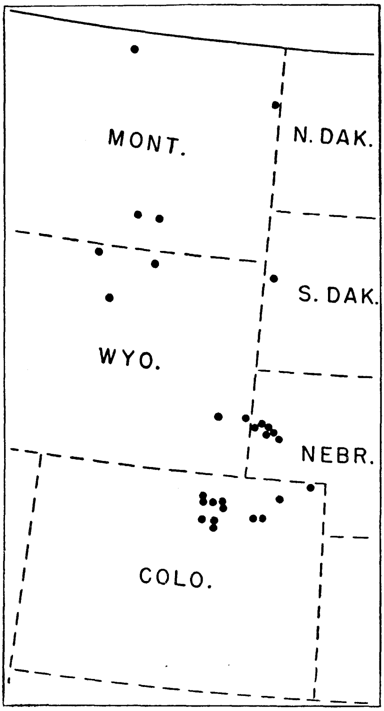

FIGURE 1.—Location of beet-sugar factories in the northern Great Plains and adjacent areas. The total acreage in 1939 allocated under the Sugar Act of 1937 for the factories shown was 361,472 acres. The sugar-beet acreage tributary to the factories, as allocated, ranged from about 7,000 acres to a maximum of 26,735 acres. The large part of a factory's acreage is usually located within a 20-mile radius of the factory.

CLIMATIC INFLUENCES

We are accustomed to recognize the direct and indirect influence of climatic factors on cultivated crops. The direct effects, such as the freezing of a crop by an untimely frost or the retarded growth caused by drought, are perfectly obvious. Indirect effects, such as augmented insect attack on a crop, traceable to mild winter conditions which permitted the survival of large populations of the insect, are less clearly manifest. Temperature, precipitation, sunshine, humidity, length of growing season, wind, and hail all have their place in determining how well a crop succeeds in a given area. A combination of climatic factors may be so unfavorable as to preclude profitable crop production unless ways and means are found to offset these effects. Thus growers in districts in which natural rainfall is too low for crop production have overcome this situation by supplementing rainfall by irrigation.

TEMPERATURE

The sugar beet is now grown in districts that have a growing season of approximately 5 months and a mean temperature of about 70° F. for the 3 summer months and slightly lower temperatures for the spring and fall periods. Sugar beets fail to make good growth during periods when the maximum day temperatures range much above 100° F.

Sugar beets are more resistant to frost injury than some of the crops grown in the irrigated districts. It has been found that temperature as low as 27° F. does not usually injure the plants either in the spring

or in the fall. Small plants just emerging through the surface of the soil are, however, more sensitive than larger plants. When the ground is moist and the seedlings have emerged and have started to develop true leaves, it is not often that a drop in temperature to as low as 25° F. will cause the loss of the entire stand. Young plants are injured more by prolonged cold, wet periods without sunshine than by frost.

In the northern Great Plains region, cool periods in the fall favor storage of sugar in the beet root. Temperatures below 26° F. usually cause foliage injury. Following such injury to the tops, a period of warm weather may bring about a growth of new leaves and a sharp decline in the sucrose content of the roots.

RAINFALL

The annual rainfall in the portions of the northern Great Plains under consideration varies from less than 6 inches to more than 20 inches, the variation from year to year being pronounced. Thus, a district whose average annual rainfall over a long period is 15 inches may have a range in precipitation somewhat less than 6 to more than 20 inches. There is also wide variation in the monthly distribution of rainfall. Sometimes the total spring and summer rainfall is made up chiefly of scattered light showers. These are of little benefit, as less than one-half inch precipitation is of small value to the growing crop.

Where spring precipitation is normally inadequate for germinating the seed, growers practice irrigation immediately following planting and usually obtain good stands. In districts where there is usually sufficient moisture for germination, either from moisture stored in the soil or from timely rains, irrigation is not commonly used. In these districts, there are usually fields with poor stands where improper seedbed preparation has caused loss of soil moisture. In the seasons in which spring rainfall is subnormal, the failure to irrigate brings about uneven and late germination.

Throughout the sugar-beet districts of the northern Great Plains, the common practice in sugar-beet growing is to disregard rainfall in July, August, and September and apply irrigation water at regular intervals.

HAIL

Heavy hailstorms are less destructive to sugar beets than to other crops grown under irrigation in this area. Hailstorms occur more frequently in the western irrigated districts than in other sugar-beet-growing areas of the United States, therefore this capacity of the sugar-beet plant to recover from hail injury is of economic importance. When hail occurs before the beets have grown four leaves or when the plants are hit immediately following thinning, there is sometimes a complete loss of stand. If, however, the plants have become established, the foliage may be almost entirely destroyed by hail, and yet at least 95 percent of the injured plants may recover. Following the defoliation by hail, new leaves are produced. Root growth is retarded for a period of 10 days to 2 weeks following severe damage by hail, after which apparently normal growth ensues. In 1938, certain high-yielding fields in the Scotts Bluff station district experienced as many as three severe hailstorms and, in spite of the set-back, which caused failure with other crops, gave satisfactory but not maximum returns.

WIND

The erosion of soil and the depletion of soil moisture are two sources of damage to soils in the course of preparation of the seedbed for sugar beets. If the soil surface is finely pulverized and level, there is often a tendency for the soil to drift or blow away. The loss of surface-soil moisture often causes serious damage by delaying germination of the beet seed, which is planted about 1½ inches deep. Certain methods of seedbed preparation (see p. 181) serve to reduce loss of soil moisture. Some sugar-beet lands are subject to damage from the winds from the time the beets are harvested until the crop planted the following year is large enough to prevent blowing of the soil. Winter damage to lands from which sugar beets have been harvested can be prevented by furrowing the soil by use of ditchers such as are used for making irrigation furrows between the beet rows. When

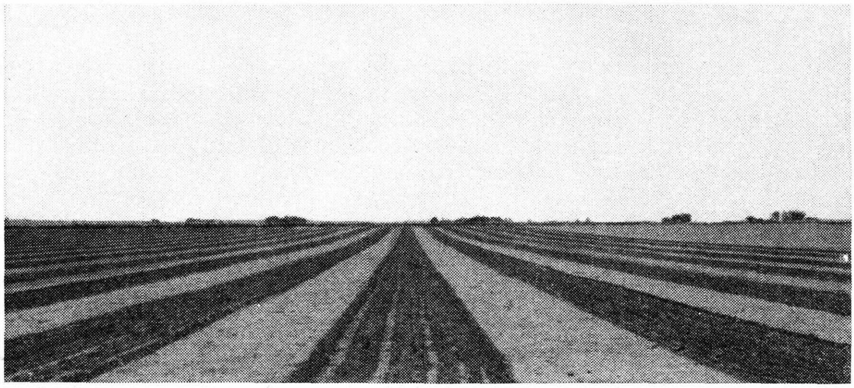

FIGURE 2.—Strip cultivation is the best method of preventing wind damage to sugar-beet fields.

the sugar-beet tops are piled on the land; it is not often that serious drifting of soil occurs.

Sugar beets are relatively slow in growing sufficient foliage to prevent blowing of the soil and are subject to damage from winds in the northern Great Plains until about June 10. When the sugar beets are planted, small furrows approximately 1 foot wide and 3 or 4 inches deep should be maintained between alternate beet rows from the time the seed is planted until the beets are large enough to thin. On sandy lands or loose seedbeds, it is a very common occurrence for beet-seed drill furrows to be depressed more than an inch below the surface of the soil, and strong winds often fill in soil over the beet seed so that the seed becomes covered too deep for good emergence of the plants. The best preventative is to prepare a more firm seedbed. In one instance, on sandy land in a loose seedbed at Torrington, Wyo., a portion of the field was planted; then the drill was stopped until the remainder of the field could be rolled with a corrugated roller. In this particular instance, the drilling was continued in less than an hour; however, the rolling made a difference of 35 percent in the harvested stand of beets.

In northwestern Nebraska, where strong winds are very frequent, over 90 percent of the growers practice blind cultivation to prevent

wind losses to the young sugar beets. This is commonly done by using a four-row beet cultivator equipped with ditchers and duckfoot cultivating tools. The ditchers follow the two furrows that were made when the seed was drilled. The cultivating tools loosen the soil between the rows not furrowed. Alternate strips of four or five rows each are usually cultivated. This is much less injurious to the sugar-beet stand than harrowing. Some growers use knives in addition to the above-described equipment for blind cultivation. Harrows, spiked rollers, and corrugated rollers are used to some extent for breaking crusts and roughening the soil surface (fig. 2).

LAND SELECTION

Careful consideration should be given to the contour of the field, the soil type, physical condition of the soil, general fertility, and previous cropping system of any field selected for the growing of sugar beets.

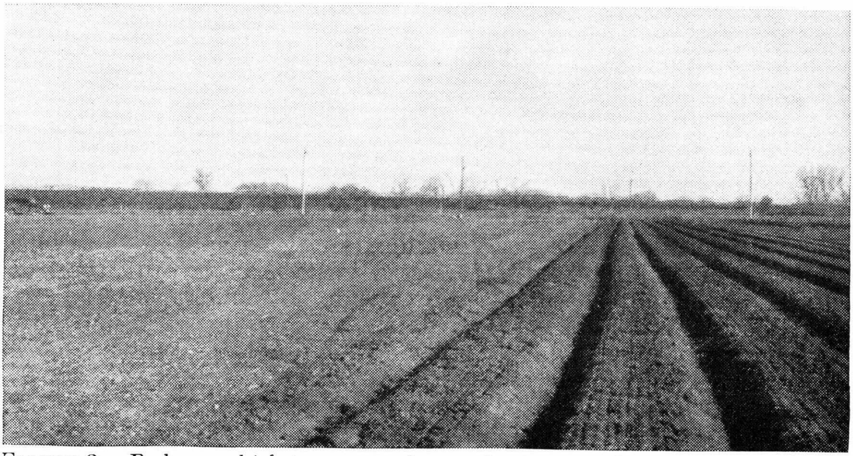

FIGURE 3.—Beds on which two rows of sugar beets are to be grown are shown at the right. To make the beds, the soil is ridged in the fall or very early spring. The crests of the ridges are harrowed off and the planting beds shaped with a special shaping sled preliminary to planting.

Any one of these factors, if unfavorable, may seriously interfere with the production of a profitable crop. In the irrigated districts, some fields are unsuitable for sugar-beet production, and the cost of correcting their deficiencies is too great for such fields to be considered potential sugar-beet lands; the majority of the irrigated fields, however, can be brought into a condition suitable for the culture of sugar beets.

CONTOUR OF THE LAND

The irrigation of sugar beets is normally practiced by the gravity system, whereby the water is run between sugar-beet rows spaced 20 inches apart. To obtain good distribution of water in shallow furrows between the rows and to avoid flooding, only very slight variations in surface levels may be permitted. Rough lands are more suited to the irrigation of hay and grain crops, or crops grown with wider rows which can be furrowed deeper. On certain types of undulating fields, ridge planting has come into use in the growing of sugar beets, as this method permits the use of deeper furrows between the rows (fig. 3).

The best type of contour of land for sugar beets is a gentle, even slope where the water can be run between the rows in furrows about 3 inches deep for a distance of 300 to 500 feet. On lands that are heavy and do not wash easily, slightly longer runs of water are often made.

Steep slopes are not suitable for the growing of sugar beets, as the water must be run in the furrows between the rows several times during the season. The repeated flowing of water between the rows on steep slopes may wash deep furrows and bring about serious soil displacement. Irrigation water must be run for longer periods on steeply sloping lands so that adequate penetration of water into the soil is obtained. In many fields, throughout the irrigated areas, dry spots are noticeable in sugar-beet fields, and these occur most frequently where the slopes of the land are abrupt.

SOIL TYPE

Many types of soil are found in the irrigated areas, almost all of which are alkaline in reaction. These soils range in type from heavy clay, medium clay, silt, or sandy loams to pure sand. Adobe, volcanic ash, and gravelly soils are also found. A sugar-beet crop can be grown on any of the better types of soil; some, however, require very skillful farming and careful handling if profitable yields are to be obtained. Water right is often more important than specific soil type. The light and medium sandy loams are best adapted to sugar-beet culture, because they are easily handled and least subject to serious crusting. They normally produce better yields than the other types of soil. Loose soils absorb water rapidly but do not hold so great a quantity as heavier soils; however, the latter are less quickly penetrated. The capacity of a soil to absorb water is of fundamental importance in determining the appropriate irrigation practice.

Heavy clay soils are better adapted to the growing of sugar beets where irrigation is practiced than where beets are grown under conditions of natural rainfall. It is characteristic of these soils that they are difficult to handle when wet or extremely dry. As the irrigated regions do not have a heavy rainfall, the clay soils are not often excessively wet, and proper irrigation can usually prevent such soils from becoming too dry. Clay soils are more subject to crusting than lighter soils but less subject to wind damage.

Beet plants start earlier on sandy soils and have a more vigorous growth for a few weeks in the early part of the growing season. During hot weather, when the demand for water is greatest, sugar beets on sandy soils often do not make so good growth as those on heavier soils. Very early planting seems to have an advantage on sandy soils, but more frequent irrigations are needed during the entire irrigating season. Light yields are more common on sandy soils than on heavier soils, but some growers seem to have overcome the handicap of sandy soils to some extent by using better farming practices, especially early planting, frequent irrigation, and adequate use of manure.

The growing of sugar beets on gravelly soils presents many of the difficulties indicated for sandy soils, and frequently soils of this type are very low in fertility.

PHYSICAL CONDITION OF THE SOIL

The physical condition of the soil depends upon the soil type to a large extent. Soil type is not subject to change except in isolated instances in which the land is filled or surface soil is removed in leveling. On the other hand, properly planned agricultural practices can be used to effect soil improvement. Controllable factors, such as cultural practices, rotation, use of barnyard manure, green manuring, and irrigation methods, have a definite influence upon the immediate physical condition of the land. This is very evident in the irrigated districts of the northern Great Plains, where farming has been practiced a relatively short period of years. Although some lands have been irrigated for over 75 years, it is known that on many farms irrigation has been used less than 25 years. Some of the more recently developed farms are in good physical condition, and others are in much worse condition now than they were when the first crop was grown. On some farms on which the soils were sandy, practically all of the original humus has been exhausted; and the soils are now light, blowing sands. In sharp contrast to these abused farm lands, nearby homesteads are to be found on which, by use of windbreaks to prevent wind erosion and by consistent addition of humus-building materials, the physical condition of the soil has been greatly improved. On all the soil types in the area, similar contrasts of humus exhaustion as opposed to soil building can be found. Soil fertility seems to be very closely related to physical conditions in the irrigated districts.

The fields in good physical condition are the ones that now grow good crops of sugar beets, whereas those where the physical condition has been permitted to deteriorate show a corresponding decline in yields. The evidence is significant that continued use of green-manure crops and application of barnyard manure improve the physical condition of all soils. As might be expected, the most decisive responses to these practices are on extremely light and extremely heavy soils.

SUBSOIL

The ideal subsoil for a beet field is one having good water-holding capacity and at the same time readily permitting drainage of excess water. The topsoil and subsurface layers should be 2 feet or more in thickness. Good drainage is as important in irrigated fields as in regions where crops are grown under conditions of natural precipitation. Neither hardpan subsoil nor very loose subsoils are desirable for sugar beets. The hardpan prevents drainage of excess water applied during irrigation, and it is practically impossible to irrigate a field amply without some excess water collecting in the lower portions of the field.

The height of the water table in the subsoil has an effect upon the growth of the beets since they are a deep-rooted crop. Under conditions of light rainfall and excessive evaporation, a high water table tends to bring about accumulation of alkaline substances in the topsoil. In some fields capable of producing good crops of sugar beets, the water table is relatively high, sometimes within 3 feet of the surface. To such fields, fewer irrigations should be applied, and at each irrigation only light runs of water should be made.

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CROP ROTATION

Among the benefits derived from a proper crop rotation, the following are of high importance: (1) A more varied source of farm income is provided; (2) feed for livestock can be provided, thus encouraging the inclusion of livestock in the farm program; (3) the labor load in crop production is distributed; (4) the demand of various crops for water is apportioned; (5) depredations of diseases and insects are lessened; and (6) weed control is fostered.

Because of some rather common misconceptions, it is probably desirable to call attention to the fact that crop rotation alone cannot produce a maximum yield of any of the crops common to these districts over any continued period of years. It is necessary to apply manures and fertilizers regularly, if gradual soil depletion is to be avoided. In general, crop rotation does not appreciably build up the plant-food content of the soil, except as the residue from a legume crop adds to the nitrogen content. Some changes may be made in the availability of mineral constituents of the soil, but additions to the totals brought about by crop rotation are small. A proper soil-management program will also take into account the use of barnyard manure and the application of commercial fertilizers as required to supply needed plant-food elements. These methods of soil improvement are closely related, as, in a well-balanced rotation, certain crops are grown to feed livestock and the manure produced is returned to the soil.

The significance of crop rotation in this area is very well shown by the unfavorable effects that have resulted when beets have been grown continuously in certain fields over a long period, as well as by the experimental evidence obtained at the Scotts Bluff, Nebr., and Belle Fourche, S. Dak., field stations of the Division of Irrigation Agriculture, United States Department of Agriculture.[2]

As a general rule, continued cropping with a single crop for a period of years usually introduces some factors that cause low yields, such as diseases, insect pests, low fertility, or some other damaging influence. With sugar beets, failure to practice crop rotation has almost always been found to have a depressing effect upon yields. In many instances, continued growing of sugar beets has brought about the production of large populations of sugar-beet nematodes and made sugar-beet growing impossible except by establishing a long-time rotation system in which host crops of the nematode are eliminated. After such a regime is established, sugar beets can be grown not more than once each fifth or sixth year. It is true that in many districts some fields are found in which sugar beets have been grown continuously for several years with good yields, if manure has been applied in ample quantities. On other fields in the same districts, nematodes have been introduced and intensified by continued culture, with the result that yields have seriously depreciated.

In the carefully conducted crop-rotation experiments at the Scotts Bluff field station, the growing of sugar beets continuously for 25 years without applications of manure has brought about a reduction of

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[2] The following publications give more detailed information on rotation studies of the Scotts Bluff, Nebr., Belle Fourche, S. Dak., and Huntley, Mont., field stations of the Division of Irrigation Agriculture: U. S. Department of Agriculture Technical Bulletin 512, IRRIGATED CROP ROTATIONS IN WESTERN NEBRASKA, 1912–34; U. S. Department of Agriculture Technical Bulletin 571, IRRIGATED CROP ROTATIONS AT THE HUNTLEY (MONT.) FIELD STATION, 1912–35; and U. S. Department of Agriculture Technical Bulletin 454, AGRICULTURAL INVESTIGATIONS AT THE BELLE FOURCHE (S. DAK.) FIELD STATION, 1926–32.

acre yield from over 15 tons to about 5 tons. Large numbers of the plants have died between thinning and harvesttime. This heavy death rate seems to be due to both a depleted soil and a concentration of beet diseases. These rotations have been conducted under close supervision with no return of dump dirt to the plots. In addition, by the use of clean tools and other precautions the introduction of the sugar-beet nematode has been avoided. The evidence is significant that continued cropping without the use of manure on these plots is the least successful method of growing sugar beets.

In these tests, rotations consisting only of cash crops have similarly given poor results as measured by the acre yields of sugar beets. For example, in 2-year rotations in which sugar beets alternate with such cash crops as oats, wheat, corn, barley, or potatoes, the acre yields of sugar beets have fallen to about 7½ tons.

In these experiments the introduction into the rotation of legume crops such as alfalfa and sweetclover, the plots not being pastured and manure not being added, has maintained the yields at a fairly high level. Similar results have been obtained elsewhere, but on certain soil types no definite benefits have resulted from this practice. Legume crops are known to reduce the phosphate content of the soil but add to the nitrogen content. On soils low in phosphate, it has been found that legume rotations were of little benefit to the sugar-beet crop unless manure or phosphate was added.

At the Scotts Bluff field station, the use of alfalfa in rotations with sugar beets and other crops has been sufficient to maintain the yields at about the 15-ton-per-acre average yield for 25 years. The addition of manure at the rate of 12 tons per acre, whenever sugar beets were grown, has produced yields of 17 to 18 tons of beets per acre. It is also noted that the original application of manure raised the production of beets to about the same level. Therefore the gains in yields by the use of legumes and manures were quickly obtained and maintained, but these practices were not sufficient to bring about greater increases in yields. It seems that to obtain maximum yields of sugar beets greater quantities of manure are needed.

The comparable rotation studies at the Belle Fourche field station have given somewhat different results from the inclusion of alfalfa in rotations containing sugar beets. As the rotations were starting, the sugar-beet yields at this station were about 4 or 5 tons below initial yields at the Scotts Bluff field station. Inclusion of alfalfa in the rotations at Belle Fourche has resulted in about 1-ton increase in acre yield of sugar-beet roots over the yields obtained in the initial years before alfalfa occurred in the rotations. The plots receiving manure applications have shown definite increase in sugar-beet yields over those obtained in the initial years before manure was applied.

SELECTING ROTATIONS

The highest yields of sugar beets have been obtained when they were grown in a rotation including legumes or, when other cash crops were grown, if manure or the necessary fertilizer was applied. The value of sugar beets in weed control is also worthy of consideration. The clean culture given the sugar-beet crop is especially beneficial in reducing the weed population of fields. The effect of this reduction can be noted in crops which follow, especially in small grains.

In the selection of rotations for the irrigated districts, requirements of the various crops for irrigation water must also be considered. Grain and alfalfa need water earlier in the season than potatoes or sugar beets. Throughout the season, sugar beets and alfalfa require more water than small grain, potatoes, or corn.

In the irrigated area of the northern Great Plains, alfalfa is the principal irrigated hay crop, and sugar beets, potatoes, wheat, and beans are grown as cash crops, while barley, oats, and corn are grown as the feed crops. Sweetclover and alfalfa are used to some extent for pasture. Various rotations can be made to fit all farms. Alfalfa is usually grown for 3 years and is planted with small grain as a nurse crop. A common 6-year rotation in use is small grain 1 year, alfalfa 3 years, potatoes or corn 1 year, sugar beets 1 year. In potato-growing areas, one of the best crops to follow alfalfa is potatoes, as this crop permits more green growth of the alfalfa before plowing under in the spring. Coupled with the use of manure, it is a common practice to lengthen the rotation by growing sugar beets 1 or 2 years following the potato crop. The widespread popularity of this rotation in the area seems to be sufficient to recommend its use until some distinctly better one is found. Variations may be made in order to introduce other crops that are profitable in a particular area. A short rotation that is rather frequently used consists of 1 year of grain, seeded to sweetclover, which is plowed late in the following spring, 1 year of potatoes, and 1 year of sugar beets.

USE OF LIVESTOCK MANURES

The mineral reserves of the soil are drawn upon to build plant substance. As each crop is removed, the soil reserves are depleted according to the drafts that the crop makes upon the different elements and the size of the crop. Continued removal of crops without replacement of these fertilizer elements depletes soil fertility, and yields are depressed. The best results in farming are obtained by the use of a combination of methods to return mineral elements and organic matter to the soil. As has been pointed out, there are fields which, after being farmed 25 or more years, are producing greater yields than they produced when first brought under cultivation. There are also nearby lands that perhaps had equal yielding capacity when first farmed that now produce low yields, due to neglect of the methods of fertility maintenance.

The soluble soil minerals are immediately available for use by plants. These are subject to loss by leaching where excess amounts of water are applied. Insoluble chemical reserves that are not removed by excess water and are not at once available for plant use are also present in soils. The unavailable reserves slowly become available as chemical changes take place that make them soluble. In addition, certain plant foods, such as phosphorus, that are added in fertilizers, may revert on certain soil types to the insoluble form as a result of chemical changes taking place. With these soils special methods or treatments are necessary to make these elements available.

Livestock manures contribute plant food elements, add to the humus content of the soil, and improve the physical condition of the soil. There are a number of instances where increased yields of crops are grown after the application of manures, and the increase in yields

is much greater than can be explained on the basis of the chemical content of the manures added. Accordingly, it is recognized that the addition of barnyard manure, because of the quickening of microbial activity and other complex reactions that are set up, brings about a condition in which plant food reserves otherwise unavailable are put into condition for the plant to use. Green manures have been found to produce increased crop returns, their beneficial action probably being brought about by similar processes.

METHODS OF MANURING

As has been pointed out, the sugar beet responds readily to applications of barnyard manures in this irrigated area. Tests have indicated that manure applications to the sugar-beet crops produce higher returns in this area than those from any other crop. The manure produced on the farm is nearly always used to fertilize the fields on which sugar beets are grown, applications being made immediately before field preparations begin.

Some growers practice pasturing of legume crops and corn by livestock preparatory to fitting the land for the sugar-beet crop. The common practice, however, is to make use of feed lots and to haul the livestock manure from the feeding enclosures and barnyards and spread it at once. The manure should not be hauled from the feed lots until it is possible to spread and plow under without delay.

Stock is allowed to feed on the beet tops from the sugar-beet crop, after harvest of the roots, on about a quarter of the beet acreage. By field pasturing, a greater recovery of the manure value is made than by lot feeding of sugar-beet tops. Another method sometimes used is to establish large temporary feed lots on fields on which sugar beets are to be grown and feed sheep for a few weeks. This adds manure to the land, but the compacting of the soil which may occur is detrimental. A greater feed value is obtained from tops that are hauled from the field, properly cured, and used for lot feeding. Because of this factor, the practice of field-pasturing beet tops is giving way, in many districts, to feed-lot utilization of this important feed.

VALUE OF LIVESTOCK MANURE

The value of manure produced by the different kinds of livestock is often discussed. It is probable that the differences observed depend more upon the moisture content and the kinds of feed and bedding used than upon the animal sources. The amount of manure that is produced by an animal unit of 1,000 pounds live weight of horses, cattle, or sheep has been determined under conditions where all of the manures were recovered, and it has been found that the differences in gross quantity vary more than net quantities of nitrogen, phosphorus, or potash. Under farm conditions, the manurial value derived per animal unit is influenced by the bedding used and the methods of handling the manure. Ample use of bedding and immediate spreading of the manure conserves more of the value of the manure than other methods. The manures accumulated in feed lots are trampled upon and packed, and thus are reasonably well conserved. In the irrigated districts where feed lots are usually dry, the storage of manures in the lots is the common practice.

Manure from dairy cattle and from wet feed lots is high in moisture. As a general rule, manure from sheep feed lots is lower in moisture than

that from cattle feed lots. Tests have been conducted over a series of years at the Scotts Bluff station in which manures from horses, cattle, and sheep were applied at various rates per acre, each kind of manure being so used that for each comparison between values of manures the same weight of dry matter was applied per acre. The control or check plots received no manure, some of the others were manured with the various kinds of manure (50-percent moisture basis) at the rate of 6 tons an acre, others at a rate of 12 tons, others at a rate of 18 tons, and some plots received as much as 24 tons per acre. In the 4 years of test no great differences in the yields of sugar beets were found that could be attributable to kinds of manure used. Where equal amounts of dry matter are applied per acre, it is doubtful if there is any considerable difference in the value of horse, cattle, or sheep manure.

The immediate gain in crop yield shown the first year the field is manured does not represent the total gain from an application. Benefits traceable to manure can be noted over a period of years, usually gradually diminishing in amount. This is true whether the crops are sugar beets, grain, alfalfa, or corn. It is not improbable that a value of 3 to 5 dollars per ton of manure applied can be shown from the increased crop yield on many farms. The manure from an individual animal unit on some of these irrigated farms is worth as much as $20 per year. The returns that are obtained depend much upon the rate of application, the value of the crop produced, and the state of fertility of the land to which the manure is applied. Crops, such as sugar beets and potatoes, that have a high value per acre will give the greatest return for the use of manure. Plots to which manure is applied at the rate of 6 tons per acre will show a greater increase per ton of manure than those on which it is applied at the rate of 18 to 24 tons per acre. Land of low fertility usually gives more response from the use of manure than land of high fertility. In the test at Torrington, Wyo., where the untreated portions yielded 8 tons of beets per acre, the use of 12 tons of manure per acre increased the yields to 12 tons of sugar beets per acre the first year, whereas at the Scotts Bluff station, on a field that yielded 16 tons per acre without treatment, the use of 12 tons of manure per acre only increased the yield of sugar beets 2 tons.

At the Scotts Bluff field station in three different rotations in which no legume crops were included, manure was used on each beet crop. As shown in United States Department of Agriculture Technical Bulletin 614, the yield of sugar beets over a 25-year period was increased to the extent of 7.2 tons per acre over that of identical rotations that did not have the benefit of manure. At the Belle Fourche, S. Dak., field station, the difference in favor of the use of manure on identical rotations that did not include legume crops was approximately 5½ tons of sugar beets per acre.

At each of these stations there are two 6-year rotations that include sugar beets. One rotation consists of sugar beets, 1 year; alfalfa, 3 years; potatoes, 1 year; and oats, 1 year, with 12 tons of manure applied per acre previous to planting of sugar beets. The other rotation is the same as to crops, but no manure is applied preceding the beet crop. At the present time, after 25 years of treatment, there is an increased acre yield of approximately 5 tons in favor of the manured rotation.

QUANTITY OF MANURE TO APPLY

In the rate-of-manuring test just discussed, the greatest increase in yield of sugar beets for each ton of manure used was obtained when only 6 tons per acre per year was applied. These yields, however, were not the highest obtained. It was found that an application of 12 tons per acre per year gave higher total production of sugar beets and represented more efficient use of land and manure. With the 12-ton rate of application, the acre yield in terms of sugar produced was as great as from the use of 18 or 24 tons per acre, as the larger amounts of manure produced only slightly higher tonnages of roots whose sucrose percentage was slightly lower. The general recommendation for these districts would be to apply for each beet, corn, or potato crop not more than 12 tons of manure per acre to land of average fertility. In a 6-year rotation with 3 years of alfalfa, one application of manure at the rate of 12 tons per acre is sufficient to maintain yields at a reasonably high level. Where the supply of manure is limited, it is better to dress lightly the entire beet acreage rather than to apply the manure heavily on only part of the beet lands.

In these irrigated districts, from 20 to 30 percent of the acreage of a farm is commonly used each year for the sugar-beet crop. Hence, on an 80-acre farm from 15 to 25 acres of sugar beets are grown annually. In order to produce a heavy crop, this acreage in sugar beets should receive from 180 to 300 tons of manure per year.

Not enough livestock is kept on the average 80-acre farm in this area to produce this amount of manure, and such as is produced is not always efficiently cared for to conserve its full value. Until the livestock on the farms is largely increased and proper care taken of the manure, farmers will need to supplement the livestock manures with green manures and commercial fertilizers, if optimum yields of sugar beets are to be obtained.

More and more, growers are coming to recognize that the present yields of sugar beets are not what could be grown were the fields manured to the extent necessary for the proper maintenance of the fertility of the soil. In other words, the total tonnage now produced in a district could be produced on a smaller acreage properly manured and fertilized. In these districts, the average yield is now between 12 and 13 tons per acre, and this yield undoubtedly could be increased from 25 to 50 percent if improved practices were followed on all farms and each acre of sugar beets grown received adequate applications of manure and fertilizer.

GREEN MANURES

ALFALFA

Alfalfa is one of the principal crops that can be used for green manuring in this area. Rye and other grains are not used to any great extent, as legume crops grow well and are more beneficial to the soil. Although a very large acreage of alfalfa is grown for hay in the irrigated districts, the amount of green manure obtained is relatively small, because plowing is frequently done in late summer or early spring when there is little green growth. A practice that is being followed by many growers when a field of alfalfa is to be discontinued is to secure a heavy spring growth to serve as a green-manure crop and plow this

growth under late in the spring. Because sugar beets should be planted early and as late spring plowing is practiced, other crops such as potatoes, corn, or beans should be grown immediately after the green manure is plowed under, to be followed by sugar beets the next season.

Another practice is to plow under alfalfa in late summer or fall without making a third cutting for hay. A beneficial effect from the green manuring thus obtained usually is to be noted on the crop that follows. Here again, it is preferable that some other cash crop immediately follow the alfalfa crop and that the planting of sugar beets should be deferred one season.

A third, and in some sections the most common method, is to break up old alfalfa sods after a close cutting of hay in late summer or fall. The alfalfa is lightly crowned and then subsequently turned under. Unless special precautions are taken to kill the crowns by drying, the alfalfa may persist as a weed. It has been noted that it is easier to prevent alfalfa survival if the plowing is done when the plant is actively growing than when it is in semidormant condition. Although it is recognized that alfalfa sods handled so as to avoid renewed growth from the alfalfa plants must sometimes be used for sugar beets, the disadvantages of this practice should be clearly understood. Contrary to popular belief and some published recommendations, alfalfa followed by sugar beets has commonly given mediocre to poor results. Frequently the so-called alfalfa sods are very old alfalfa fields that have become excessively grassy. It is difficult to prepare these soils so as to obtain for sugar beets a firm seedbed free from air pockets. The green-manure and nitrogen values commonly expected from alfalfa are not obtained in full measure, because plowing is usually done when the fields are relatively bare, or on old alfalfa fields, and the actual stand of alfalfa may be scant. The nitrogen supply in such fields frequently is low, in sharp contrast to abundant nitrogen supply of young full stands of alfalfa. Furthermore, the sequence of alfalfa and sugar beets has frequently been found associated with poor stands of sugar beets, because damping-off, commonly called black root, and also root rot are accentuated. It has often been observed that damage from white grub, wireworm, and cutworms is more severe when alfalfa sods are used for sugar beets.

The problem of utilizing alfalfa fields to their full advantage is a pressing one in the entire irrigated district. Where other cash crops in addition to sugar beets are grown, these can very profitably be grown immediately following the alfalfa crops, sugar beets appearing later in the rotation. Here the problem resolves itself into utilizing to the full extent the green growth obtainable from the legume. When it is necessary to have sugar beets follow alfalfa, green manure should be turned under before September and then speedy decomposition should be brought about by irrigation of the field.

SWEETCLOVER

Sweetclover has come into widespread use as a green-manure crop and when thus used is seldom cut for hay. A common practice is to plant sweetclover with small grain as a nurse crop. If the resultant growth of sweetclover is plowed under the same year, not much benefit results, as in this area the late summer seasons are usually dry, and the growth sweetclover makes after the grain is cut is commonly

small. As a result of a number of careful tests it has been found that, although in occasional seasons considerable growth of sweetclover is obtained, usually growth following the cutting of grain cannot be relied upon for heavy production of green manures. Furthermore, if such a sweetclover field is to be planted with sugar beets at a reasonably early planting date, the sweetclover must be fall-plowed or, if spring-plowed, turned under before any spring growth has started. As with alfalfa, poor stands of sugar beets commonly result when sugar beets immediately follow sweetclover. It is the common experience with plowing under in late fall or early spring that the sweetclover persists as a weed. Hence, for a very small increment of green manure, the sugar-beet grower is inviting other difficulties.

Consideration should also be given to the practice of permitting sweetclover to grow to a height of 8 to 10 inches before spring plowing, thus delaying planting the sugar beets 1 month in order that more

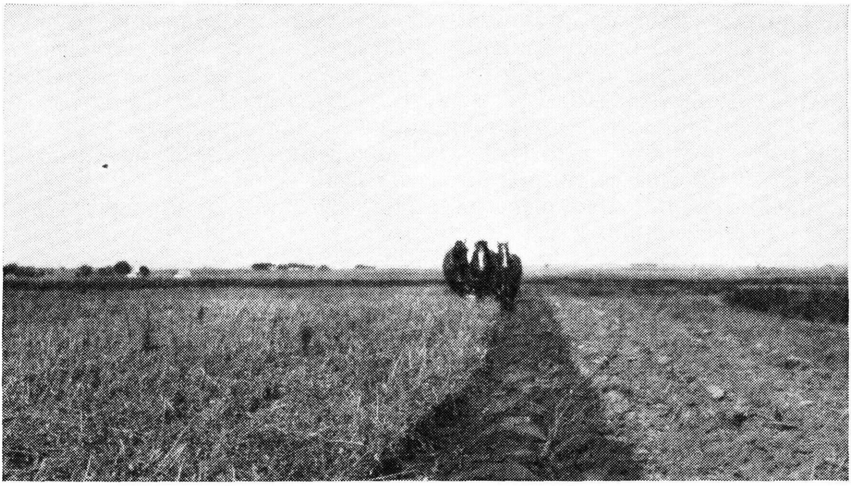

FIGURE 4.—Plowing under a heavy crop of sweetclover, which has been disked.

green manure may be added to the soil and the sweetclover be more completely killed by plowing under. If such practice is followed a proper seedbed is more difficult to obtain; and irrigation must promptly follow planting to assure better germination. It is probable that this practice would give yields substantially better than those from early-plowed sweetclover, especially as sugar beets often have to be replanted on the early-plowed sweetclover fields. Either practice is hazardous and, as a general rule, unnecessary.

Better yields of sugar beets are obtainable if the potato crop or other late-planted cash crop is grown the first year after sweetclover. The sweetclover may be permitted to make a spring growth of 2 to 4 feet before it is plowed under and a crop such as potatoes planted. The following year the soil is in excellent condition for sugar beets. In tests at the Scotts Bluff station yields equal to those obtained on lands where sweetclover was pastured a full season have been produced by this method. In some instances the increase above the yield of plots receiving green manure amounted to 3 to 5 tons per acre (fig. 4).

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PASTURING ALFALFA AND SWEETCLOVER

Alfalfa and sweetclover may be pastured for a full season before being plowed under. Less green manure is obtained by this method than if the legume crop were not pastured. However, the livestock manures that are added to the soil more than compensate for the smaller amount of green manure.

Pasturing as a means of harvesting alfalfa and sweetclover, and some other crops, is coming into increased use throughout the area. Where corn is harvested by being pastured by sheep or hogs, the manure returned greatly benefits the soil. The feeding of sheep in cornfields has been found satisfactory, providing dry hay is fed also to prevent the consuming of too much grain. These are more specialized forms of pasturing, the common practice being to pasture cattle, or hogs, on alfalfa or sweetclover. Satisfactory gains in the livestock come from this type of feeding. When the livestock is put into the field early in the season and not removed, bloating seldom occurs, in contrast to results from occasional pasturage on this succulent forage. The yields of sugar beets grown on land on which legumes have been pastured compare favorably with those from land that has had a heavy green-manure crop plowed under. Also on many soils the yields are very similar to those obtained where barnyard manure is applied at the rate of 12 tons per acre.

Efficient use of the pasturing method with legumes requires planning, so that fields regularly become available for the livestock. Alfalfa can be pastured during the entire season and for more than 1 year. However, the usual custom is to grow alfalfa for hay for a limited period and then pasture it 1 year before plowing the field. Sweetclover does not provide pasturage for more than 1 year. Where a rotation is practiced, a sweetclover field started the previous year provides pasturage early in the season and until the new planting of sweetclover, which was started in grain, is ready. By planting a field each year, a practically continuous pasturage can be obtained during the growing season. It is desirable in pasturing livestock on either alfalfa or sweetclover to fence the field so that the animals are confined for a few days in one part of the field while the other portion is permitted to grow. Such a procedure avoids the damage that comes from trampling when the field has been recently irrigated.

COMMERCIAL FERTILIZERS

Commercial fertilizers were not used for growing sugar beets in the irrigated districts of the northern Great Plains until the late 1920's, as it was generally believed that yields would not be increased by their use. The soils in these districts are extremely variable; when they were first brought under cultivation, they contained large quantities of phosphate and potash, largely in insoluble forms, however. Certain soils were very high in calcium. It is now being noted that many of the soils high in phosphate have become low in available phosphate. The potash supply is probably still adequate, as evidenced by the fact that in these districts potash has not been found to be commercially profitable as fertilizer for sugar beets. As culture of crops has proceeded, the original nitrogen content of soils has tended to go down. In large part, this decrease has been offset by

growing legumes, which supply nitrogen to the soil when plowed under, and by the return of manures produced by the feeding of legume hay. Nevertheless, in some trials, nitrogen fertilizers have shown profitable returns. The cost of nitrogenous fertilizers is to be reckoned with in determining its value as a source of nitrogen as compared with legume crops turned under.

The principal fertilizer material found necessary on soils in this general area has been phosphate. This plant-food material should be used wherever field tests indicate that it gives profitable returns. There are laboratory methods in use for the testing of soils for available phosphate, and, from these tests, attempts are made tc estimate the response from the use of phosphate fertilizers. But, in general, the most reliable method of finding whether phosphate fertilizers induce profitable response in sugar beets is to make reasonably heavy applications to strips in the field and determine the yields from treated and untreated areas of the same field.

Certain factors may be taken into account in working out an adequate fertilizer practice. A ton of sugar beets removes from the soil approximately 4 pounds of nitrogen, 0.8 pound of phosphate, and 8.4 pounds of potash. A ton of tops and crowns contains slightly larger amounts of these elements, but, since in common practice these are fed on the farm, these plant-food elements are partially returned to the soil. A 15-ton sugar-beet crop removes about the same number of pounds of nitrogen, phosphate, and potash from an acre of ground as is removed by a 400-bushel crop of potatoes, a 50-bushel wheat yield, or a 50-bushel corn yield. An alfalfa crop of 4 tons per acre contains approximately the same number of pounds of phosphate and potash but a larger amount of nitrogen. The nitrogen in the alfalfa is largely obtained from the air, except in old alfalfa fields. In general, the nitrogen content of the soil is built up as leguminous crops are grown. The grain crops remove slightly less potash than the sugar beets or potatoes, but for general purposes, in these districts of high potash soils, this is not of immediate consequence. These figures roughly indicate that, in general, heavy yields of the common crops deplete the soils of phosphate to approximately the same extent. It is a common experience that fields that have been in alfalfa for several years need phosphate fertilizers before good sugar-beet crops can be grown.

The common rate of application of phosphate for growing sugar beets in this area is 100 to 200 pounds per acre of treble superphosphate, carrying from 43 to 45 percent of available phosphoric acid. If all of the phosphate could be appropriated by the sugar beet, this would be ample phosphate to produce a crop of 15 tons or more. Recommendations applicable for soils generally cannot be given, because the amount of phosphate available in the soil, the rate of reversion of applied phosphate, the binding capacity of the soil, all are factors affecting the rate of application. The determination of the amount to apply must be made for particular soil types in each locality, and the grower may well begin by following the best local practice.

COMBINATION APPLICATION OF MANURE AND PHOSPHATE

Although the rate of phosphate application cannot be given as a blanket recommendation, it is possible to outline a combination of

phosphate and manure applications that serves to make moderate applications of phosphate effective. Supplementing barnyard manure with superphosphate is valuable on those lands in the irrigated area where phosphate is deficient. An experiment was conducted at Torrington, Wyo., in a field in which phosphate gave strong response. In the test, treble superphosphate (43 percent phosphorus pentoxide, P_2O_5) was applied at the rate of 150 pounds per acre. Some plots were left untreated. Feed-lot manure was applied to plots at the rates of 6, 12, 18, and 24 tons per acre, one-half of each plot being phosphated and the other half receiving only the specified manure application. Two years of test in this field indicated that the acre yield of roots from plots without any treatment was about 9 tons and the acre yield of indicated-available sugar, 2,455 pounds. In the 2 years of test, plots treated with 150 pounds of phosphate fertilizer gave average acre yields of roots amounting to 12.1 tons, the yield of sugar being 3,621 pounds per acre. Plots treated with 6 tons of manure gave an acre yield of roots of 13.4 tons, the acre yield of sugar being 3,662 pounds. By the addition of 150 pounds of phosphate fertilizer to 6 tons of manure per acre, an average acre yield of roots amounting to 15.4 tons with an acre yield of 4,326 pounds of sugar were obtained. The average yield from the plots receiving manure at the rate of 12 tons per acre with no phosphate was 1 ton less of root weight and about 130 pounds less sugar per acre than was produced from the plots receiving 6 tons of manure and 150 pounds of phosphate fertilizer. In this test, the maximum profit per acre was obtained by the use of 6 tons of manure and 150 pounds of treble superphosphate; the larger amounts of manure (12, 18, and 24 tons per acre) did not give increases in yield to warrant the heavier applications.

The results of this test have been given in some detail, because this combination treatment probably has widespread applicability. With many soils in the northern Great Plains, definite phosphate response is shown, but an efficient practice has not been developed. Evidence exists that frequently relatively heavy phosphate applications to sugar beets have not given commensurate returns. It seems likely that, for these soils, the combination treatment consisting of moderate applications of manure and phosphate will be valuable.

SEEDBED PREPARATION

The objective in seedbed preparation is to fit the land for seeding so that a uniformly distributed stand of sugar-beet seedlings is secured from which the spaced stand may later be obtained. The quantity of seed drilled is such that, with good conditions for germination, the plants stand ½ to 1 inch apart in the rather closely spaced rows. This heavy rate of seeding is employed to compensate in part for the heavy mortality that frequently occurs in the first week after germination. The record of harvested stands in this area over a period of years shows that the average grower harvests only 65 percent of a full stand. Much of this failure to secure good sugar-beet stands traces to improperly prepared seedbeds; therefore, detailed discussion is given of the various operations in seedbed preparation.

Seedbed preparation includes the mechanical operations of plowing, harrowing, disking, leveling, and occasionally spring-tooth harrowing and rolling. In addition to the mechanical operations directly used

in fitting the soil for planting, the previous handling of the field, manuring, irrigation, drainage, and crop rotation influence the type of seedbed obtained. Different soils require somewhat different treatment in order to secure a good seedbed. Under some conditions, it can be made with a minimum expenditure of labor. The timeliness in the operations affects the quality of seedbed obtained.

Maintenance of soil moisture content is one of the very important factors to be considered in the preparation of seedbeds in this area. A moist, firm, and deep seedbed is required for growing sugar beets. The soil must be worked to a fine texture, and the surface should be firm and free from air pockets, smooth, and level. A few clods about an inch in diameter on the surface of the soil serve to prevent wind movement of the surface soil, but large clods are objectionable.

Those growers who depend upon moisture accumulated in the soil from winter rains must give special attention to firming of the seedbed and retention of soil moisture. Growers who practice irrigation to germinate seed need to be concerned with these phases of seedbed preparation to somewhat lesser extent, as the effect of early irrigations is to compact the soil. It is noteworthy, however, that a loose seedbed when irrigated settles irregularly and that this unevenness interferes with uniform water distribution and seed germination. The packing of the seedbed is more difficult if the various operations of fitting the soil are carried on with dry soil.

The plowing of entire fields before harrowing, and delays between the different operations, such as harrowing, disking, and leveling, permit the surface soil to dry out. Moisture is better conserved when leveling and harrowing are done as one operation, or with intervals of less than 1 hour between them, than if a day or two is allowed to elapse between these operations.

PLOWING

Plowing is done to pulverize the soil, incorporate manure into the soil to a proper depth, kill weeds, and destroy weed seeds or insects. Plowing in the irrigated area is more often delayed by the lack of moisture than by the surplus of moisture. Wet plowing packs the soils, except the very sandy types, which are sometimes plowed when very wet to form some clods to prevent blowing of the surface and to pack the seedbed more firmly. Usually a medium amount of moisture in the soil permits a good job of plowing. Careful harrowing immediately after plowing conserves moisture and pulverizes the soil much better than delayed harrowing (fig. 5). Subsoiling is not practiced in the irrigated area and has not been found beneficial except on a few lands that had hardpan very near the surface. The use of the two-way plow is common in plowing, as it eliminates dead furrows, which interfere with irrigation.

The common practice has been to plow deeply, 10 to 12 inches, for sugar beets. However, there are some growers who now consider the deep plowing necessary about 1 year in 3. No very extensive tests have been made in this area upon which any definite recommendations can be based as to depth of plowing for sugar beets. However, it is considered that deep plowing is a good practice with heavy soils. Deep plowing apparently does not decrease the yields, and, in many instances, it is questionable whether the yields are

sufficiently increased to pay for the extra labor involved. Some recent experiments indicate that where plowing is done immediately before planting, and not much time elapses for the settling of the seedbed, shallow plowing is preferable to deep plowing. If equal yields can be obtained by plowing 6 or 7 inches deep instead of 10 or 11, the cost of growing the crop can be somewhat reduced, but this needs further testing. Very few growers plant sugar beets on land that has not been plowed in the preparation of the seedbed, but occasionally plowing may be omitted. Very sandy soils are not benefited so much by plowing as are heavier soils. If the soil of fields from which sugar beets, potatoes, or beans were harvested the previous year is in very mellow condition the following spring, sometimes it can be put into condition for planting by disking or other types of surface preparation. It is possible that moisture is conserved to some extent by the omission of plowing, and the cost of production of the crop is somewhat reduced.

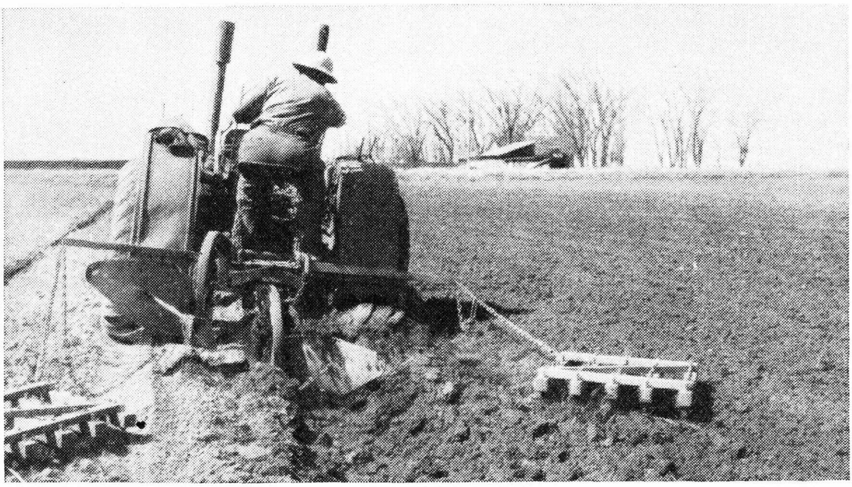

FIGURE 5.—Plowing and harrowing as one operation.

Failure to plow under weed seed often increases the labor necessary to remove weeds from the sugar-beet crop.

Fall plowing may be recommended as being generally a desirable practice on irrigated land in the northern Great Plains. Fall plowing aids in conserving moisture, especially with the heavier soils where unroughened surfaces would allow winter rains and snows to run off or evaporate. Fall-plowed land is in shape for prompt and efficient fitting in the spring; hence the sugar-beet crop can be planted early. Fall plowing also has advantages in mellowing the soil. Where sugar beets follow small grains, it is advisable to spread manure and plow the land during late summer or early fall. This practice destroys certain insects common in soddy or weedy land. However, certain modifying conditions must be taken into account that may make fall plowing inadvisable. With loose sandy soils, fall plowing might lead to the soil being subject to serious wind damage during winter. With certain crops, such as potatoes or sugar beets, the land is rough after harvest. It presents for trapping of winter moisture almost the condition obtainable by fall plowing. As plowing can rarely be done

in the northern Great Plains region during December, January, or February, growers commonly cannot manure land that has been occupied by late-harvested crops and plow it before freezing weather occurs. The handling of manure supplies may thus influence the extent to which fall plowing is utilized. Larger quantities of manure are available for spreading early in the spring than in the fall. Growers frequently do not consider the benefit from fall plowing sufficient to make up for the greater difficulty that is encountered in incorporating the manure in the soil. As an alternative to spreading manure in the spring, manures are sometimes left in feed lots over summer, but some loss of manurial value may take place. Although fall plowing is to be strongly endorsed where feasible, it is recognized that conditions may warrant deferring the plowing till spring.

PLOWING ALFALFA LAND

Alfalfa is a very common crop in the irrigated areas, and many growers plant sugar beets immediately after plowing out alfalfa. This practice, however, is definitely on the decline. Plowing alfalfa in early spring is not practical for sugar beets, as too many plants survive and become weeds in the sugar-beet field when alfalfa is plowed under in a dormant state. Crowning the alfalfa, either in early fall or spring, by plowing about 4 inches deep, is practiced, and after a period during which the crown is allowed to dry, the ground is again plowed to a depth of 8 to 10 inches. If the crowns are harrowed out on top of the ground, they usually die, and few plants survive. A more desirable practice is to avoid the double plowing by planting some other crop than sugar beets immediately after alfalfa. As previously stated (p. 13), plowing late in the spring so as to gain the benefit of a green-manure crop when discontinuing alfalfa is the approved method of changing the rotation, potatoes and corn being more desirable crops than sugar beets to plant following alfalfa.

DISKING AND ROLLING

Disking of plowed land is practiced to some extent. However, not so much benefit is derived from disking land after it is plowed as from disking it before plowing. Disking after plowing packs the subsurface of the plow slice to some extent, but usually leaves too fine a mulch on the surface. Disking before plowing lessens labor in plowing and aids in incorporating manures in the soil. This is true of both barnyard and green manures. Pulverizing the top 2 to 4 inches of soil with a disk causes the plow slice to crumble, and fewer large clods are formed. A much firmer seedbed can be formed by disking on most lands; hence disking previous to plowing is recommended on all lands except those that are very sandy. Subsurface packers are better than disks for packing plowed fields.

Rollers are not used to any great extent in the preparation of the seedbed for sugar beets. They are occasionally necessary in firming the surface of loose seedbeds and are especially beneficial in firming sandy soils, if used when the sandy soil is moist. Smooth rollers are not used, as the corrugated rollers are much more effective. The leveler, which is everywhere used in this area to prepare land for irrigation, takes the place of the roller for smoothing the land. Sub-

surface packers and other implements that are modified rollers are more effective than rollers for most of the operations for which a roller is commonly used in other areas (fig. 6).

HARROWING

Practically all growers use the spike-tooth harrow in preparing land for sugar beets. The most important harrowing is the one that is given immediately following plowing. Where tractors are used, this harrowing is often done as the land is plowed. Pulverizing and packing the soil to some extent are advisable in this area immediately following plowing whether spring or fall plowing is practiced. One harrowing at this time usually accomplishes more than several harrowings later. As leveling leaves almost all the small clods below the surface and harrowing tends to leave these clods on the surface, after the land is leveled it is customary to harrow beet fields in the opposite

FIGURE 6.—The corrugated roller is more effective than the smooth type of roller.

direction to that in which the rows are drilled in order to prevent blowing.

LEVELING

Land leveling is essential for the proper irrigation of a crop, such as sugar beets, which is grown in narrow rows and requires several irrigations during the season. Many of the fields on which the sugar-beet crop is grown still need to be leveled by the use of fresnos or scrapers, which transfer quantities of soil from higher areas to lower areas. This can be done only at a time of year when no crop is on the land. Sometimes a few days spent in this type of work make a great difference in the time required for irrigation, in addition to saving land and water. Because tractors have become more common, much greater effort is being made to improve field surfaces.

Smoothing the land to correct any minor roughness caused by previous cropping or preparation is accomplished by the use of com-

mon box-type levels (fig. 7). These levels are of several kinds and may be home-made or manufactured implements. The home-made ones are usually from 14 to 20 or more feet long and 8 to 10 feet wide. Four horses or a tractor is required to pull those commonly used. Commonly the levels have three crosspieces, which pick up soil in high places and deposit it in the depressions. These levels do not usually carry soil any great distance and are effective only in correcting areas that are from a few inches to a few feet long and wide. For leveling, the ground must be somewhat drier than is necessary for plowing or harrowing. There are some types of levels that have the middle crosspiece adjustable so as to operate more in the manner of a fresno, and these make some major improvements in the surface of the field. They are heavy implements and, in most instances, pack the surface of the soil efficiently for planting sugar beets. Where the

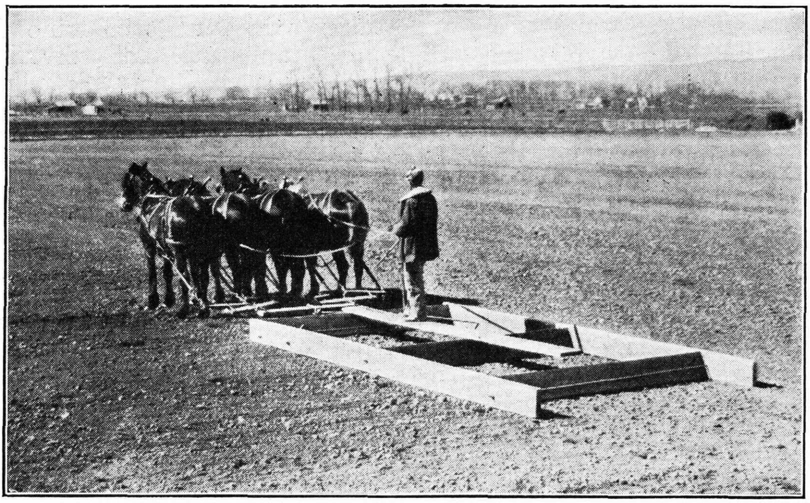

FIGURE 7.—Land leveler in operation.

land is dry, they do not always pack the subsurface; hence these implements should be used when the soil is slightly moist.

For many growers, leveling completes the preparation of the seedbed for sugar beets. However, a light harrowing is advisable as a final operation. Some growers level the land once before plowing where the previous crop has left the land uneven. Two levelings after plowing are common in preparation of the seedbed for sugar beets, the second across the direction of the first.

SEEDING

The stand of sugar beets obtained is directly influenced by the rate of seeding, depth of planting, viability of seed, the planting date, and seedbed preparation. The desired rate of seeding and the depth of placement of the seed are obtained by proper adjustment of the sugar-beet drill. Emphasis needs to be given to methods effective in crust breaking to foster emergence and to the importance of early cultivation after the seedlings emerge, if a good initial stand is to be obtained.

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Control of diseases or insect attacks that may seriously reduce stands is also important.

Beet seed as used in the northern Great Plains region has been either home-grown or imported from Europe. Some sections use home-grown seed to the exclusion of imported seed, and others have planted both kinds. It is probable that very soon only home-grown seed will be used. The home-grown seed, as a whole, is to be preferred to imported seed as it is cleaner and brighter and is produced from better adapted varieties.

SUGAR-BEET SEED DRILLS

Several types of sugar-beet drills are in widespread use in the irrigated districts. Certain types show some advantage under special conditions, but skill in operation and adjustment of the drill usually has more effect upon the stand of sugar beets than the type of drill. Drills with the usual types of fertilizer attachments combine the operations of seed planting and fertilizer application, the fertilizer being placed in the furrow with or near the seed. This type of placement does not seem to be disadvantageous when the fertilizers are principally phosphate compounds and the application rate per acre moderately low. There are some special types of fertilizer attachments for sugar-beet drills that place the fertilizer beneath the seed or in bands slightly to one side of the planted seed.

With the drills now in use, two common types of feeding arrangements are employed—the plate feed and the force feed. The plate-feed drills are inclined to leave some of the larger seeds in the drill but are more easily adjusted for even drilling of the seed than the force-feed drills. The plate-feed drills are not so inclined to be stopped up by beet-seed dust, but if there are sticks in the seed the drills may become clogged. Either type of feed drill is satisfactory, if the seed is reasonably clean and care is used in their operation. A skillful operator keeps on the alert to be sure at all times that the seed is running evenly through all the planting spouts.

Both shoe and disk types of furrow openers are in common use in the irrigated districts. Adjustment of the shoe attachments to obtain an even depth of planting is somewhat more difficult than is the case with the banded-disk drills; but when shoe attachments are carefully adjusted, satisfactory work is done. Shoe furrow openers do not operate so well as the disk types when the soil is wet but work better than the disk types on compacted soil. Old, worn attachments of either type do not operate so well as new, keen-cutting equipment. The force-feed and plate drills are furnished with either the shoe or disk types of planters; hence the grower may select a drill equipped to fit his needs.

Sugar-beet seed before being delivered to the growers is screened to eliminate all very small seed. When the planting is done with plate-feed drills, it appears that medium-sized seed is planted more uniformly than is either the large or small seed. In some planting tests conducted at Belle Fourche, S. Dak., in 1931, European sugar-beet seed was regraded into large, medium, and small sizes. The acre yields of roots obtained from the medium-sized seed were about 1 ton larger and of slightly higher sucrose percentage than were obtained with either the large- or small-sized seed. As about 25 percent of the seed in the regrading was large, 50 percent medium, and 25 percent

small, the gain of medium-sized seed over bag-run seed probably was small. If the sugar-beet seed is not clean, the removal of small sticks, stones, etc., so that the seed is less likely to clog the drill, is of more importance with ordinary seed of high viability than is the size of the seed. Domestically produced sugar-beet seed commonly is better cleaned than the usual run of European seed.

Horse-drawn drills in use are arranged to plant four rows at a time. Tractor drills usually plant six rows. The fields are generally cultivated with the same power as was used in planting. Although many other operations are being done on the farm with the tractor, the greater prevalence of horse-drawn drills at present is largely due to the hold-over of equipment purchased before tractor drills were available.

After the seed drops into the furrow made by the furrow opener, the press wheels firm the soil over the seed so that it may obtain moisture and germinate evenly. If the soil is dry, then the pressure applied by the press wheels must be increased over what would be used with slightly moist soil. If the soil is moist to wet, the pressure must be lessened. The adjustment of the pressure needs careful attention. Frequently worn press wheels are responsible for poor stands.

Seed should not be planted unless the seedbed conditions are favorable. Before the planting of the seed begins and frequently thereafter until planting is completed, the following items should be carefully checked and proper adjustments made:

The amount of seed delivered from each drill spout over a measured distance should be weighed separately, and the amounts being delivered per acre calculated.

The seed hoppers should be cleaned to remove trash, dust, or very large seed that may have accumulated.

The ditchers or irrigation furrow openers should be put on the drill frame to make furrows between alternate rows to provide for irrigation and to aid in preventing wind damage.

The depth each shoe or disk penetrates the seedbed should be checked. All rows should be planted at the same depth.

The springs on the press wheels should be set so that the soil is properly firmed around the seed.

The marker should be adjusted so that the guess rows are planted at proper width.

The neck yoke and straps should be tightened so that the tongue does not sway up and down, or sideways.

The neck yoke and doubletrees should be of such length as to prevent either horse from walking on the drill row.

RATE OF SEEDING

The rate of seeding with sugar beets is usually from 15 to 20 pounds of seed per acre, the higher rate being the more prevalent. Under ideal conditions a perfect stand is obtainable with a smaller quantity of seed of the usual standards of germination; however, the sugar-beet seedling is small and relatively tender. It is subject to a very high rate of mortality during its early periods of growth. In order to obtain a sufficient number of plants to give a uniform stand after thinning, the common practice is to plant the seed in continuous drilled rows from which plants are selected for the permanent stand.

The desired initial stand is one in which it is possible to leave a plant within 2 inches of the proper interval in 90 percent of the places. A common spacing is 100 beets to 100 feet of row. Experience shows that a sparse distribution of beets in the initial stand usually produces

uneven stands after thinning. A heavy rate of seeding sometimes produces so many beets that thinning is more difficult. The possibility of loss of stand and enforced replanting is a common and expensive hazard that accompanies skimping the seed allotment. The climate of this area during the early stages of growth of the sugar-beet plants is so variable that full stands, even with the planting of excess quantities of seed, are the exception rather than the rule.

Four years of tests of seeding rates have been conducted at the Scotts Bluff station in which 10, 15, 20, 25, and 30 pounds of beet seed were planted in replicated plots. The test showed that planting at the rate of 20 pounds of seed per acre was preferable to planting at higher or lower rates. The sucrose percentages of sugar beets grown with different rates of seeding were not significantly different. The average acre yield of roots obtained by planting 10 pounds of seed per acre was 1.2 tons lower than the yield obtained from the use of 20 pounds per acre and 1 ton less than the yield obtained in plots in which 15 pounds of seed per acre was used. The acre yields of roots were neither decreased nor increased significantly by planting more than 20 pounds of seed per acre.

The size of the seed balls from different sources varies somewhat. Very small seed balls flow from the drill more freely than larger seed balls, compensating for the fewer true seeds in the small-sized seed balls.

DEPTH OF PLANTING

In this area where rainfall is infrequent and winds are drying, the planting of sugar-beet seed less than 1 inch deep is not practical, as the surface of the soil usually dries rapidly. Studies of the emergence of the sugar-beet plants in relation to planting depth show that very few plants appeared above the surface when the depth of seed placement was greater than 2 inches. These conditions limit the depth of planting of sugar-beet seed within the range between 1 and 2 inches; most growers attempt to plant the seed 1½ inches deep. In dry ground the seed is sometimes planted as deep as 2 inches. Early in the season or when the ground is very moist, the seed is planted only 1 inch deep. Provided conditions for germination are favorable, the plants emerge more rapidly and have somewhat stronger stems when the seed is planted 1 inch deep than when it is planted 2 inches deep. Tests of planting beet seed at depths of 1 inch, 1½ inches, and 2 inches were conducted on nine different fields during seven different seasons. These tests were made at the Scotts Bluff station, at Torrington, Wyo., and at the Belle Fourche station. The results from this series of replicated experiments indicate that slightly higher yields were obtained by planting the seed 1½ inches deep than when it was planted at the other two depths. The sucrose percentages and apparent purity coefficients did not show any significant differences attributable to planting depth. The average acre yield of roots was 15.0 tons on the plots planted 1½ inches deep, 14.4 tons on the plots planted 1 inch deep, and 13.8 tons on the plots planted 2 inches deep.

A common difficulty experienced in sugar-beet plantings in this area arises from improperly prepared seedbeds. Planting may be made at the proper depth, but the effect of the press wheels is to make a depression along the drill furrow so that the surface of the row is 1 inch or more below the field level. Winds or heavy rains deposit soil

in this furrow so that the seed is deeply covered or the young plants become covered as they emerge. Attention to seedbed preparation tends to eliminate this hazard. Rolling after planting is advised if there is indication that the press wheels have sunk into the soil.

DATE OF PLANTING

If moisture conditions are favorable, sugar-beet seed germinates well when the soil temperature is approximately 60° F., slightly higher temperatures producing more rapid germination. Apparently among the sugar-beet plants there are some having more resistance to freezing than others, since when frosts occur a portion of the plants survive. Usually plants that are a week or two old tolerate cold exposure better than plants that have recently emerged. As the frosts may occur for several weeks after what would be classed as an early date of planting sugar beets, it is advisable to plant early or medium early rather than defer planting to avoid chance of frost damage. Usually in this area the moisture content of the soil for germination is most favorable to the early planted seed. Delaying the planting of a portion of the beets a few days, so as to distribute the labor of thinning, is not advisable where the land can be properly prepared in time for early planting, because the damage from a small delay in thinning is not so great as that which comes from a reduced stand occasioned by late planting.

Obviously, no calendar date for planting sugar beets can be given, as weather conditions vary from season to season. In the irrigated districts of the northern Great Plains region, there are more sugar beets planted from April 15 to April 30 than during any other similar period of planting season. When conditions are favorable, planting may begin during the first week in April. On the other hand, a few fields may be planted as late as the first week in June. In the ordinary seasons, plantings that are made in the middle of May are considered late. The popular opinion is that early beets have a higher sucrose percentage than those planted late. But this is not always the case. In tests in which different dates of planting were tested in the same field, it has been found that early planted beets have a higher sucrose content than those planted late only during those years that sugar-beet leaf spot was absent. During leaf spot years, late-planted beets commonly at harvesttime have a higher sucrose content than those planted early. During a 5-year period of testing in Nebraska, Wyoming, and South Dakota, no significant sucrose-content differences were found between early and late planted beets when the period of planting ran from April 5 to May 15. In plantings made before April 25, significant differences in acre yields of roots were not found among those planted on dates that would range from early to medium early. In plantings made between April 25 and May 15 the acre yields of roots were found to decrease about 1 ton for each 10-day delay after April 25. A factor to be taken into consideration in the irrigated districts is that the planting date, which is usually definitely recorded, may not be the significant date in the starting of growth in the sugar-beet field, since, because of lack of rainfall, early plantings do not always start ahead of later plantings.

The planting of sugar-beet seed in March, when the season was such that the ground was in condition for planting, has been tested, and in

some seasons the yields and stands were as good as those of plantings made from April 5 to 25. It is probable that sandy lands should be planted earlier than heavy lands.

Replanting because of poor stands is a practice that is declining, as it has been found that ordinarily a good stand cannot be obtained by replanting to replace the early stand. The yield from a relatively poor stand of early beets may be better than that obtainable from a later planting. Hence, replanting should not be considered without careful weighing of probable chances for the field as it is. Moisture conditions frequently are unfavorable for late replantings. If the field is to be replanted it is usually essential that irrigations be used to bring up the crop.

SOIL-CRUST CONTROL

In Nebraska, South Dakota, Wyoming, and elsewhere in the irrigated districts it is not unusual in April and May to have dashing rains followed by strong dry winds that form heavy crusts, especially on

FIGURE 8.—The light, one-horse beet harrow formerly in common use for crust breaking.

the heavier soils. Sugar-beet stands are frequently severely injured by the formation of crusts on the soil at the time the seed is germinating. Heavy crusts are most frequently mentioned as the cause of stand injury to sugar beets, but severe injury has been observed that has been brought about by very thin crusts. On sandy lands of high calcium carbonate content it has been found that frequently a light rain will cause a cementlike crust about one-fourth inch thick to form. As the young plant, seeking to push up through the soil, encounters the crusted soil, emergence cannot take place unless a block or flake of soil is pushed up.

Formerly harrowing was the most common method used to break the crusts on sugar-beet fields. In most instances the harrows used were light implements especially designed for shallow top-working, pulled by one horse (fig. 8). Harrows of this type did not dig very

deeply and did not disturb the seed. They were used before the plants emerged and served efficiently in preventing crust formation up to fairly late in the germination period. The present practice is to use a beet cultivator for breaking the crusts on sugar-beet fields, as it does a better job for the following reasons: The horses do not walk on the drill row, and the outline of the row remains visible; the furrows between the rows can be maintained so as to prevent blowing of soil; and harrowing, especially late in the germination period, is objectionable because the harrow may cover or dig out plants and some stand is lost by each harrowing. Two or three harrowings may almost destroy a sugar-beet stand, but with repeated cultivation the stand is not destroyed.

The common cultivator tools are sufficient for most fields, as the breaking of the crust between the rows causes sufficient cracking of

FIGURE 9.—Cultivation begun as soon as the rows could be followed. The crust is sufficiently broken so that damage is avoided. The ground is rough and cloddy so that wind effects will be lessened.

the crust in the row to permit the sugar beet to continue growth (fig. 9). A special type of spiked-roller attachment for cultivators has come into use for pulverizing the surface of the soil in the beet row. These attachments are especially beneficial when the crust is dry and hard, although the subsurface soil is moist and mellow (fig. 10).

Operations performed for the prevention of crust formation are much more efficient than the operations performed after the crust has formed. The common custom is to begin cultivation as soon as the field ceases to be muddy and the soil does not stick to the cultivating tools. The ground is often somewhat wet for tillage, but the dangers of wind damage or crust formation are much greater than that of the packing effects of wet tillage (fig. 11).

After the sugar beets are through the surface of the soil and a crust forms around the seedlings, some growers attempt to break this crust to aid the young plants. Tests indicate that as much damage may be done to the crop in breaking the crust as would be done by the crust if it were left undisturbed. Yield tests conducted at the Scotts

Bluff station on replicated plots do not indicate that the differences in yields are sufficient to pay for the extra labor. Cultivation or harrowing of the sugar beets after a hard crust has formed shifts

FIGURE 10.—A spike-tooth attachment for the cultivator used to break crust in the rows of sugar beets.

portions of the crust and kills many beets by shearing them off at the point where the crust loosens from the soil. The proper method is to cultivate before the heavy crust forms.

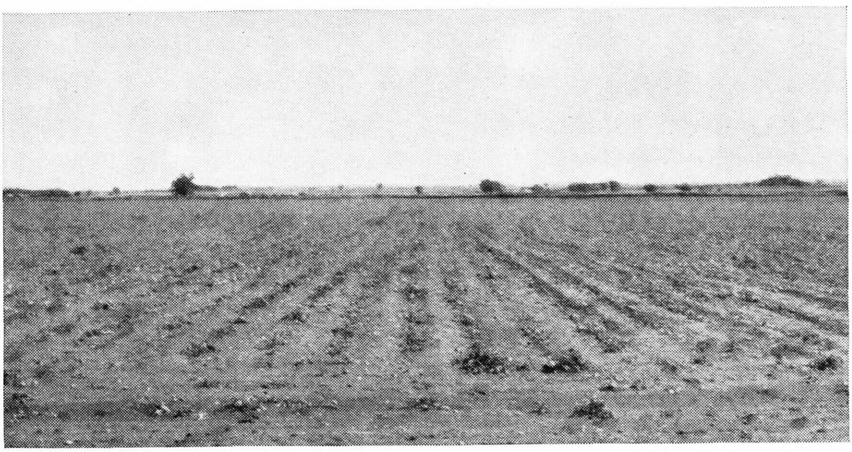

FIGURE 11.—An unthinned field of sugar beets, which was hit by a light hailstorm followed by heavy rain. To prevent crusting and wind damage. cultivation should be begun as soon as the field is partially dry.

HAND BLOCKING AND THINNING

Blocking and thinning consists of the hand labor necessary to remove surplus plants from the sugar-beet rows so as to leave the singled plants from which the crop is to be produced. Blocking and thinning may be performed as separate or as combined operations. Usually

more than one plant grows from a seed ball; hence it is not possible to plant only sufficient seed to produce the desired stand, as is done with corn or beans. Because heavy seeding is practiced and the plants stand close together or in clumps, hand labor in removing the surplus plants is required in order to leave a stand of beets spaced singly about 12 inches apart in the row. This labor is sometimes done by the grower but is more often contracted to laborers, who do the work at a set price per acre. Blocking and thinning of an acre can be

FIGURE 12.—Blocking of sugar beets with a short-handled hoe and hand thinning being done as one operation. Each laborer works two rows and should free the rows of weeds and leave each plant with the soil firmed around the roots.

done by the expenditure of from 20 to 40 hours of labor, depending upon the efficiency of the labor and the condition of the field. Thinning and blocking as a combined operation requires less labor than separately blocking and thinning. Short-handled hoes are used when the two operations are combined and commonly two rows are thinned at the same time. Whether thinning and blocking are done as combined or separate operations has little effect upon the quality of the work done (fig. 12).

Sugar beets can be most efficiently thinned when the plants have from 6 to 8 leaves, but the practical conditions of growing the crop require that some of the plants be thinned before they have reached

this stage of growth. In some cases the thinning of fields may be delayed until the plants have from 10 to 12 leaves. Ordinarily, thinning can begin about 3 weeks after the seedlings emerge. Thinning should not be begun on any field until the majority of the plants have 4 leaves. Germination and growth of sugar beets are somewhat uneven, and in most fields considerable differences in the size of plants

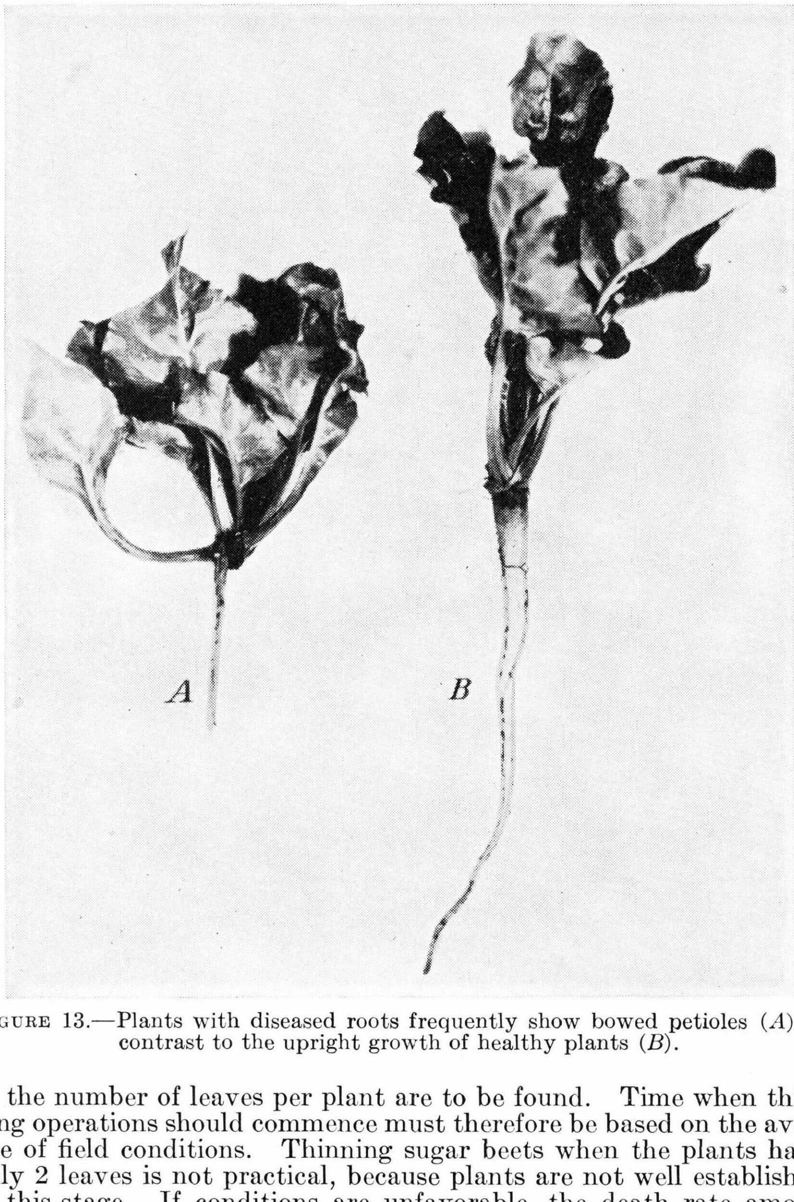

FIGURE 13.—Plants with diseased roots frequently show bowed petioles (*A*) in contrast to the upright growth of healthy plants (*B*).

or the number of leaves per plant are to be found. Time when thinning operations should commence must therefore be based on the average of field conditions. Thinning sugar beets when the plants have only 2 leaves is not practical, because plants are not well established at this stage. If conditions are unfavorable, the death rate among the thinned stand left is extremely high. Delaying the thinning until

the beets have 10 to 12 leaves usually reduces the yields. Soil moisture and fertility are depleted to some extent by delay in thinning. As the beets become larger, the injury in removing the excess plants to the plants left standing also is increased; replicated tests conducted for a number of years in Nebraska, Wyoming, and South Dakota have indicated gains in yields of about 1 ton per acre for plots thinned when the beets have 4 to 8 leaves over those in which the beets were thinned at either the 2-leaf or the 10- to 12-leaf stage.

The time of thinning is also influenced by the prevalence of damping-off, a seedling disease, commonly called "black root" by growers. The general effect of damping-off is to kill young plants, seriously depleting the stand. As damping-off produces most severe effects on very young plants and the attack comes here and there along the drill row, it is essential when this disease is operative in the field that thinning be delayed until affected and nonaffected plants

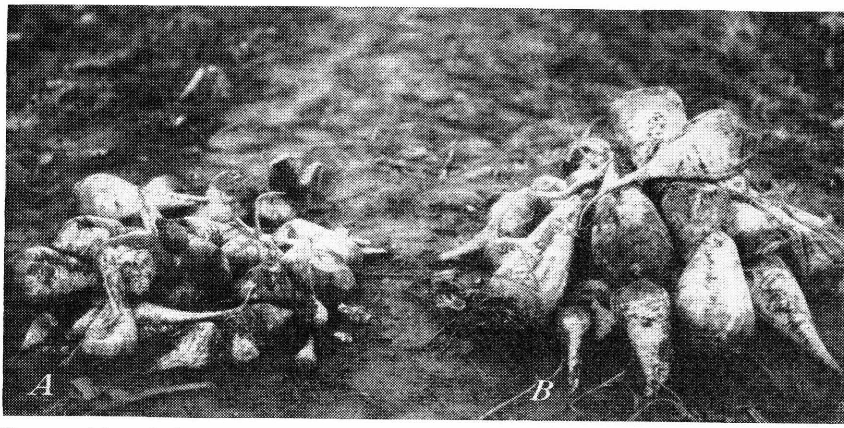

FIGURE 14.—*A*, Sugar-beet roots grown from plants that were noted in the spring to have partially recovered from damping-off. *B*, Roots produced by plants that were classified as healthy.

can readily be detected, also to permit the most seriously infected plants to die and disappear. It has been noted that older seedlings that have diseased roots often develop thickened, bowed leaf stems in sharp contrast to the straight leaf stems of healthy plants (fig. 13). Furthermore, the affected plants lag markedly in growth as compared with those that are unaffected. By selection at thinning time so that large, sturdy plants are left, diseased plants may largely be avoided. The value of such selection to leave the healthy beet should be stressed strongly. In experimental work conducted at the Scotts Bluff station a large number of disease-affected plants that were surviving at the six-leaf stage and stood adjacent at proper spacing to healthy plants were marked. Their growth in comparison with their healthy neighbors was followed through the season. Approximately one-third of the diseased plants died early, one-third produced rotted roots or roots too small to be of commercial value, and one-third produced harvestable roots. A diseased plant left at thinning time apparently has limited chance of survival and represents more of a liability than an asset in the sugar-beet field (fig. 14).

In stands that show little or no damping-off (black root), the leaving of the largest and healthiest plants at thinning time also is advisable. In tests in which the largest beets at thinning time are actually left, the yield has been found to be greater than that obtained from the medium-sized seedlings. When the smaller beets were left, the yield was found to be seriously reduced.

The aim in thinning is to leave sugar-beet plants standing singly at as regular intervals as possible in the row and to leave standing the largest plants without injury by removal of soil from the row. The old prejudice against doubles being left here and there in the row probably was not altogether justified. Two beets left close together probably do not either increase the yield or injure it to any appreciable extent. The labor of topping two beets, however, is greater than that of topping one. All weeds in the row not reached by cultivation should be removed.

SPACING IN THE ROW

In this area, the standard distance between rows of beets is 20 inches, and the spacing between beets is 12 inches, which with a full stand would give 26,136 sugar beets per acre. There has been considerable effort expended for a period of years to induce growers in some areas to grow the beets closer than 12 inches in the rows. The average yields from beets grown under different conditions, and during several seasons, indicate that the yield is not greatly varied by spacing in the rows when the intervals are between 8 inches and 16 inches. Work required for the thinning and topping is increased with close row spacings. On the other hand, spacing at a greater row interval than 12 inches requires less labor, therefore small losses may sometimes be absorbed by other savings where beets are spaced slightly wider in the row. In proper spacing of sugar beets allowance should be made for unoccupied places in the row, because of skips in planting or death of plants before or after thinning. Uniformity of stand is very important; however, this is not controlled as much by thinning operations as by the uniformity of the stand before thinning.

In 5 tests conducted in Nebraska, Wyoming, and South Dakota between 1930 and 1937, in which the beets were spaced 6, 9, 12, 15, or 18 inches apart in the row, the beets spaced 6 inches apart produced 16.62 tons of roots per acre, with a sucrose percentage of 15.25, and the beets spaced 18 inches apart produced 16.70 tons of roots, with a sucrose percentage of 14.80. In the same area during the same period of time 5 other tests were conducted in which the beets were spaced respectively 8, 10, 12, 14, and 16 inches apart in the rows. These replicated-plot tests produced 15.5 tons of roots per acre from 8-, 12-, 14-, and 16-inch spacings as against 15.4 tons from the 10-inch spacing. The sucrose percentage of the beets from the 8- and 10-inch spacings was approximately 17.3; from the 12- and 14-inch spacings, 17.1; from the 16-inch spacing, 17.0. These 10 tests indicate that closer spacing increases sucrose percentages somewhat, although there is no indication of significant effects upon the acre yields of roots.

MECHANICAL BLOCKING AND CROSS-CULTIVATION

Mechanical blocking can be done with the ordinary beet cultivator equipped with common cultivating tools, such as duckfeet, or with special tools designed to shear off the plants more efficiently (fig. 15).

In operation, the cultivator is drawn at right angles to the rows, cutting out a portion of the row and leaving, at regular spacing, blocks of beets subsequently to be thinned. In addition to the beet cultivator, special machines to block beets are now being developed and tested.

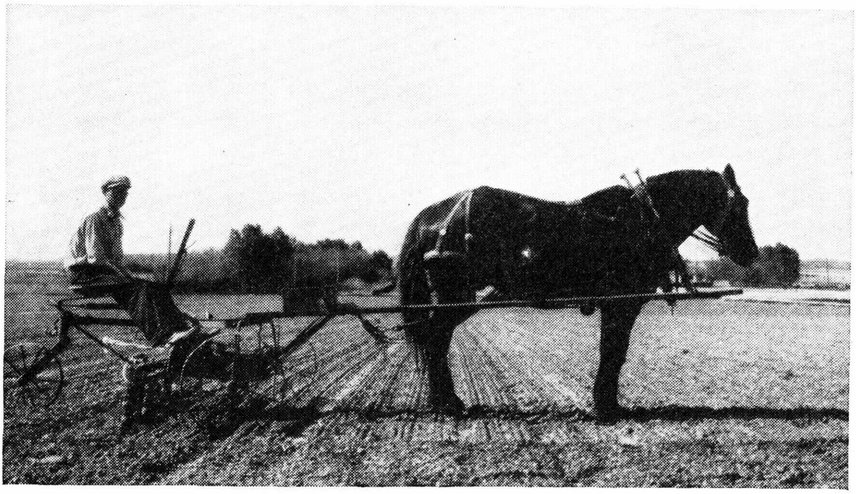

FIGURE 15.—Cross blocking of sugar beets by cultivating across the rows. Several of the better practices are shown in this illustration. One horse does the work easily and tramples fewer beets than a team; the work is done when the plants are small. The field has been rolled to prevent the covering and shearing off of plants by clods or crusts.

FIGURE 16.—A four-row machine which blocks beets as it is drawn along the row.

These operate along rather than across the rows. Because purchase of special equipment for blocking entails added expense, these machines must show efficiency in operation over the ordinary cultivator in cross blocking for them to come into widespread use (fig. 16).

If cross blocking is done, it should precede thinning by 2 or 3 days at least, and several days may elapse between the two operations. The present method is to leave 4 inches and cut out 8 inches of row, or leave 3 inches and cut out 7 inches. The general character of the stand must be taken into account in deciding the block width to be left.

Introduction of cross-cultivation on mechanically blocked fields as a practice in growing sugar beets in the irrigated area has lagged, chiefly because the making and maintenance of the furrows for irrigation become more difficult when cross-cultivation is practiced. It has a definite advantage with weedy fields. Up to the present, cross-cultivation has proved to be most popular in districts, such as the Red River Valley of Minnesota, in which the spacing of the beets from 16 to 20 inches apart in the rows is rather commonly used and where beets are grown without irrigation.

Mechanical blocking of sugar beets has been advocated and used to a limited extent in the irrigated area for several years. There have been a number of demonstration fields sponsored for instruction of growers in the methods. The use of mechanical blocking during the past 5 years has not greatly increased, which indicates that the growers are not fully convinced that the present methods of cross blocking are suited to their conditions. However, cross blocking is a labor-saving practice and should not be expected to increase yields. The occasional increase of yields which comes from cross blocking fields that are weedy or fields where thinning must be delayed is in its favor. If the initial stand has serious skips in the rows, the stand left by mechanical blocking may be less desirable than that which is left by hand labor. In the irrigated districts, at present, hand laborers are not fully in favor of mechanical blocking. The laborers also object to the covering of beets that occurs in the blocking-out operation. In hand blocking, the surviving beets are left in better condition for thinning.

HOEING

About 10 days after the sugar beets have been thinned, the hand laborers go over the fields to cut out all weeds in the rows. The spaces between the rows are usually entirely free from weeds at this time, as cultivation, when properly done, kills all weeds except those in the row and in the narrow band 1 or 2 inches wide on each side of the row. The first hoeing takes more time than the second hoeing, which is done late in the season to remove the few tall weeds that grow up in the field about mid-August. The labor involved in the first hoeing depends upon the kind of thinning job done and the efficiency of the cultivation. Very early thinning is sometimes responsible for increased labor of hoeing, because more small weeds survive than ordinarily are left when larger beets are thinned. Hand laborers are inclined to want to thin beets when they have only two leaves, but at this time the weeds are very small, are harder to see, and are not efficiently removed. Beets that are thinned after they have eight leaves are seldom weedy at hoeing time. Small beets can be thinned more easily than larger beets, but the total labor of thinning and hoeing is more nearly equal for different sizes of beets up to those having 10 or 12 leaves at thinning time. Some growers attempt to have the hills in which the doubles occur rethinned at the time of the first hoeing, but this cor-

rection does not increase the yield. Removal at the time of the second hoeing is not advisable. Doubles should not be left at thinning time; but when they have been left, it is not worth while to expend the labor necessary to remove them.

CULTIVATION

WEED CONTROL

Obtaining a clean stand of sugar beets by cultivation is less difficult in the irrigated area than in the humid regions where weeds are a more serious problem. The principal value of cultivation is to kill weeds. The benefits from cultivations when the plants are very small to prevent wind damage have been mentioned (p. 41). In these districts, the chief value of breaking the crust around beets that have two leaves or more comes from preventing soil movement. Other benefits attributed to cultivation, such as improvement of the condition of the soil by loosening, promotion of aeration, and conservation of moisture, seem of relatively minor importance in the irrigated districts.

Weeds usually start in the beet fields in this area at the time the beets germinate and during the period from May 1 to June 15. The average field of sugar beets requires not less than two cultivations primarily for weed control. One of these cultivations is given before thinning and one after thinning. If these two cultivations and the thinning have been carefully done, the weed problem for most fields is solved. Weeds do not germinate in the beet rows to any great extent when they are irrigated by furrows. The maintaining of a dust mulch on the surface of the soil in the beet fields is not a very difficult problem when rainfall is infrequent or comes as light showers. It is only when heavy storms cause new crusts to be formed that additional cultivations besides those necessary to kill the weeds are employed, if it is desired to loosen the topsoil.

NUMBER OF CULTIVATIONS

The number of cultivations for sugar beets varies with seasonal conditions, but during normal seasons a good crop can be grown with three cultivations, as follows: Before thinning, about June 20, at which time the irrigation furrows are deepened, and before the leaves are large enough to cover the space between the rows. On lands that are difficult to irrigate, a furrowing after the first irrigation is necessary. Some growers cultivate their beets more than three times. However, tests of methods of cultivation conducted at Belle Fourche, S. Dak., in 1932, 1933, 1934, and 1935 do not indicate that under normal conditions any better yields are obtained with four, five, six, or seven cultivations than with three cultivations. In these same tests, beets were grown with no cultivation except the furrowing for irrigation and also with one and two cultivations. No significant difference in yield was obtained between any of the treatments. However, it was noted that more hand labor was required to thin and hoe the beets unless two cultivations were given in addition to furrowing. The extra cultivations above three indicated some loss in stand where too many were given, and this would offset any advantage that may have been gained by numerous cultivations. As the yield was not increased, these extra cultivations represent a loss of labor, therefore the rec-

ommended practice is to cultivate only to kill weeds and, if desired, to make a mulch.

SHALLOW VERSUS DEEP CULTIVATION

Deep cultivation was commonly practiced when sugar beets were first grown in this area. The depth of cultivation for sugar beets should not be greater than 2 inches, preferably less. Deep, close cultivations have been recommended early in the season. However, the depth should be only that which is necessary to destroy all weeds, as deeper cultivations cover too many beets with earth. Some growers maintain that deep cultivation is necessary to keep the ground loose enough to provide sufficient loose soil to permit making irrigation furrows of proper depth. The fact seems to be that whenever a field has become so dry that difficulty in furrowing is encountered, the irrigation has been too long delayed. One should not wait until the crop is suffering from lack of moisture before beginning the furrowing operation. It is better to prepare the furrows early so as to be ready to irrigate.

A study of the root system of the sugar beet indicates that early in the season not much damage is done to the sugar beet by deep cultivation unless it is very close. However, by the time the leaves have begun to spread to the extent that they cover the rows, the roots have grown to a much greater distance, and deep cultivation is undesirable. Normally, the spread of the leaves of a beet plant is somewhat less than half that of the roots. The sugar-beet plant obtains about two-thirds of its moisture from the top foot of soil and only one-third from lower depths, which indicates the amount of damage that can be done to the feeding roots of the plant by needless, frequent, or deep cultivations.

In cultivation tests conducted in South Dakota, five deep cultivations were compared with five shallow cultivations. The average yield for the shallow cultivations was 0.8 of a ton greater than that of the deep cultivations, a statistically significant difference.

METHODS

The tools needed for cultivation of the sugar-beet crops are: Knives (the adjustable types are preferable); duckfeet, which are of two sizes (the small ones, 4 to 6 inches wide, are all that are needed in conjunction with knives); shovels or furrow openers, which are of two sizes (the larger, flatter ones operate best in most fields).

A few growers use disks to cultivate very close to the rows just before thinning; however, for most fields, adjustable knives can easily take the place of disks. Where there is too much coarse manure or trash in the fields, the disks are easier to operate than knives. In setting the tools on a beet cultivator, the first tools to place on the tool bar are those in the center directly in front of the third wheel. The other tools can be properly spaced in relation to the setting of the center tools. Tools should be set so that they have a tendency to dig into the ground. The depth of cultivation can then be controlled by setting the hand lever so that deep penetration is prevented. If cultivation close to the row is desired, the tools operating in one row are adjusted to cut slightly closer to it than the tools operating on the other rows. This row is watched to prevent cultivating out

the plants. The neck yoke and doubletrees of a beet cultivator should be of a length that keeps the horses from walking on the row. Trimming the hoofs of large horses sometimes prevents much injury to beets from trampling. A well-managed and properly trained team will not walk on the sugar-beet plants or cut out many of them.

IRRIGATION

The selection of any given piece of land in the northern Great Plains for growing sugar beets should include consideration of the amount, source, and dependability of the water supply for irrigation. The availability of irrigation water varies for different farms in the irrigated districts, because many methods are used in assigning water to the lands. Usually land and water are sold as one item. The value of the farm depends somewhat upon the type of soil, but to an equal extent it depends upon the water available for irrigation of the crops. Many farms on which the land had a value of $5 or less per acre as dry land have been made into farms worth $100 or more per acre by making available an ample water supply. The cost of bringing water to the lands often involves a large construction charge. There is usually a small yearly charge, ranging from less than $1 to $3 per acre for delivery of water. The cost of delivery of water should be investigated before land is purchased.

Water for irrigating sugar beets in this area comes from three sources: Direct river flow, which is normally greatest early in the spring when rainfall is most abundant and melting snows increase the stream flow; reservoir or storage waters, which are floodwaters held back during the times of heavy flow and distributed as needed; and water from underground sources obtained by pumping. Utilization of the last-named water source has gradually increased during the past few years. Many farms have water from two or more sources of supply. In general, direct-flow water is the least costly but, being dependent upon precipitation, the available supply fluctuates. Normally the supply is ample early but may be insufficient during the latter part of the sugar-beet irrigating season. Land with early priority of rights for the use of direct-flow water is sometimes well supplied; land with later priorities is often meagerly supplied. Storage-water supplies depend upon reservoir capacity, number of users, and seasonal variations in the amount of water available for storage. The greater portion of the sugar beets in this area are grown by using storage waters to supplement the direct-flow supply. Water obtained by pumps tapping underground water is, on a limited number of farms, the only source of water supply, but in the majority of instances it has been developed to supplement direct-flow or storage water supply. Irrigation with pumped water usually is more expensive but has the valuable features of immediate availability and individual control and provides a supply of water at any time during the growing season.

Commonly, gravity flow is practiced in bringing the water to the farms and in distributing the water over the lands. Sprinkling or overhead distribution of water is not used.

To secure drainage for irrigated land requires proper attention to the disposal of surface waters, and occasionally it is necessary to provide drains for excess underground water. The disposal of excess surface waters is necessary because some water must be permitted to

flow off the field in order to irrigate the lower end of the field without puddling. Water should not be accumulated around the beets as it may cause scalding. Waste ditches and leveling, as previously discussed, are necessary.

NUMBER OF IRRIGATIONS

The average field of sugar beets in this area requires from three to seven irrigations per season, depending upon the type of soil, rainfall, water table, and evaporation. Some beets are damaged by too much irrigation. However, this is limited almost entirely to fields that have a high water table and those that are too rough for even distribution of water. More fields are permitted to suffer from lack of irrigation than are damaged by overirrigation.

IRRIGATION METHODS

Supply laterals for irrigating sugar beets should be sufficiently close to prevent excessive watering of the upper end of the rows before the lower ends are adequately watered. A common improper practice in irrigating sugar beets is to fail to distribute the water in a sufficient number of furrows. Setting the water as small streams in the furrows prevents washing, uses less water, and avoids breaks from the furrows. On many fields, it would be profitable to use some means of assuring even distribution of small streams of water to the furrows. The past few years of drought and low water supply have caused many growers to give attention to methods of obtaining better distribution and care of water. Some are lining ditches to prevent seeping; others are using pipes, lath boxes, and perforated flumes to aid in distributing water to the furrows. Any of these devices is expensive to install but will save water and reduce the cost of labor for irrigating. Night irrigation of sugar beets is very difficult without mechanical aid in distributing the water in the proper furrows, but where water is limited it is often profitable to use these specialized methods. The average irrigator can handle at one set about 75 furrows of water in a sugar-beet field where the land is normal for irrigation. Twice that number can be managed well if perforated flumes are used for distributing the water.

TIME OF IRRIGATION

Irrigation should begin whenever the soil is deficient in moisture. The normal rainfall of this area may provide sufficient moisture for germination of the seed; however, in many years irrigation is needed. In order that irrigation water may be applied to germinate the seed, the necessity of irrigation furrows being made between alternate rows at the time of planting has been stressed. It is advisable to apply water within 24 hours after planting. If application of the water is delayed, a portion of the seed may be in soil moist enough to sprout it; the rest may remain ungerminated. Uneven stands, because of such unevenness in germination of the seed, are very common where irrigation is delayed. Flooding for germination is not advisable, as a hard crust often forms; however, sandy lands that subirrigate slowly are very difficult to irrigate without flooding. Irrigation of the young plants normally begins in this area from June 20 to July 5. The common practice is to irrigate at intervals of 10 days to 2 weeks. The final

irrigation is ordinarily given not later than September 15. The frequency of irrigation depends upon many factors and is a problem of individual fields and individual seasons. In this area, the early season is usually one of the less frequent irrigations than midseason because of normal rainfall and lower temperatures and because the leaf surface is smaller than it is later in the season.

When the growing of sugar beets first began in the irrigated districts, it was commonly believed that irrigating early in the season would prevent the beet roots from growing deeply and would cause branching. This has not been found to be correct. Branching of the main root of sugar beets arises from a number of causes, such as high water table, loose seedbed, and insect or disease injuries. Where straw or haystack bottoms are plowed under there are often many beets with branched roots. As stated, the first irrigation should be given when the soil begins to lose its friable, moist feel, and this general criterion holds for time of giving a water application whether it be when the seed is planted, before the beets are thinned, or at any other time during the season. The sugar beets should not wilt or lose their fresh green appearance. Whenever the leaves turn a dark green color or fail to recover from midday wilting during the evening, irrigation should not be further delayed. It is better to make the irrigation furrows and apply water before the ground becomes hard than to try to cultivate deeply enough so as to be able to make furrows after the ground is too hard for easy furrowing. The last irrigation of the season should be applied late enough to assure that growth will continue until frost kills the leaves and that the soil will still be moist enough for easy lifting of the crop. Where water is limited, it is better to apply the water before the beets are seriously damaged by drought than to attempt to save the water for later in the season. Intervals between irrigation may be slightly lengthened when the water supply is inadequate.

Over a period of 4 years, irrigations were made at Belle Fourche, S. Dak., to test the effects of beginning irrigation about June 20 in comparison with delaying until July 1 or July 10. During the period of this test, irrigation for germination was not necessary. The general findings were that if less than 1 inch of rain fell from June 20 to July 1, the delay in irrigation reduced the acre yield of roots 1 ton; in years when at least 1 inch of rain fell in this period, there was no loss of tonnage. Sucrose percentages were similar with all dates of irrigation. Delay in irrigation after July 1 was found almost always to bring about a loss in yield. In the areas where the beet root aphis commonly infests sugar beets, it has been discovered that the winged migrants of this insect usually come to the beet fields during the last week of June. If the soil has been recently irrigated at this date, the infestation of roots is reduced a considerable extent. In the Nebraska districts, it is commonly recognized that after irrigation is begun a series of light irrigations, about 10 days apart, give better yields than less frequent and heavier individual applications. One of the most serious faults in irrigation practice is the tendency to delay the first application of water.

The average irrigation of beets uses from 3 to 6 acre-inches of water per irrigation, including run-off. An acre-inch of water is a definite volume; it does not imply depth of penetration; that is determined by the permeability of the soil and other factors. In irrigating for

germination of the seed, the land is usually loose and absorbs large amounts of water. Usually it is sufficient to irrigate alternate rows during irrigations for germination of the seed or before the beets are thinned. Because the zone of root distribution is relatively shallow, there is no need early in the season to wet more than the top foot of soil if the surface can be moistened without the use of more water. At any stage of growth, the sugar beet has more feeding rootlets in the top foot of soil than in the lower feeding areas. It does, however, have roots penetrating as deep as 6 feet below the surface.

Beet roots normally extend laterally about 3 feet in each direction from the base of the plant, and as the distance from the plant increases, or as the depth increases, the concentration of roots becomes less dense. There is no need to wet more than the top 2 feet of soil during any irrigation, and the average soil will not hold more than 6 acre-inches of water in the top 2 feet of soil. The sugar beet obtains approximately 65 percent of its water from the top foot of soil and 85 percent of its moisture from the top 2 feet. The natural storage of water in the soil and deeper penetration of excess waters usually provide for sufficient moisture in the area below 2 feet. Keeping the top foot moist is the most important factor in irrigation of sugar beets. This requires more frequent but less heavy irrigations. If too much water is used, the soluble plant foods are carried out of the soil or to depths from which they are not readily recovered.

HARVEST

The operations included under the general heading of harvest of sugar beets are: Pulling, topping, loading, hauling, and delivery of the beets to the receiving station. Many of the harvesting operations have an influence upon the weight of the beets harvested and their sucrose percentage. This is especially true of the time when a field is harvested. The harvest season begins when the purchasing companies announce their readiness to receive the crop. Usually preliminary tests of quality have been made by sampling fields throughout a district, and when enough fields have reached acceptable quality as shown by test, the harvest is begun. The grower has the choice of starting the lifting and topping of beets for immediate delivery or withholding harvesting. The irrigated districts of the northern Great Plains are subject to early winter freezes, and it is not possible to delay harvest for more than a few weeks. At present few beets are harvested in the first week of October, in contrast to the situation a few years ago, when the harvest was begun the last week in September. This is largely because of a better appreciation of the fact that, normally, considerable growth is made during late September and the early part of October. Improved roads and improved equipment, especially trucks, have had a decided effect in making it possible to defer the date of harvest and take advantage of fall growth. Previously, because the beets had to be hauled by teams over poor roads, inability to speed up hauling forced many growers to begin harvest before the beets had reached their maximum root size or sucrose content.

When the crop development justifies, early harvest has certain advantages. The hand laborers are usually able to perform their tasks with less effort when the beets have not had their tops injured

by frost. Pulling is often less difficult early in the season because the soil is more moist. Snow sometimes occurs during the late harvesting periods in the irrigated area, and if it is deep, the loss of sugar beets from covering may become a considerable item. Lifting of beets may be interfered with late in the season because of freezing of the soil. Also early harvesting gives time for fall plowing and land preparation for the succeeding crop.

Deferring the lifting and topping of sugar beets until reasonably late in the harvest season has definite advantage over early harvest if the beets are in a stage of active growth during the early part of October. The normal temperatures for the latter part of September and early October are during many years favorable for increasing both root weight and the sucrose percentage of sugar beets. Increase in weight of roots continues until the foliage has been killed by a severe frost. An outstanding example of the increase in sucrose percentage that may occur was obtained from a series of samplings from one field, taken each day during the month of October at the Scotts Bluff station, during a season when no killing freeze occurred until November 1. This field was in a very green-growing state during the first days of October, and the average increase in sucrose percentage was at the rate of 0.1 percent per day for the entire month. Sugar-company daily records of the sucrose percentage of beets sliced, so far as these records deal with roots delivered directly from the field and not stored roots, indicate somewhat similar general increase in the factory average until a killing freeze occurs. Except as special conditions, such as rotting of roots, strong regrowth of tops following early freezing, or leaf spot defoliation require early harvest, the grower should generally defer or proceed slowly with harvesting until fairly late in the season. Then the harvest should be completed as rapidly as facilities permit.

LIFTING

The roots are lifted by horse- or tractor-drawn lifters that loosen and slightly raise the roots. The ordinary horse-drawn type lifts one row at a time, whereas tractor lifters sometimes pull two rows. Lifting equipment that is improperly adjusted or has worn parts, especially the puller points, improperly lifts the beets and either leaves beets that have not been loosened or wastefully breaks off the lower portions of the roots at too high a point. These losses may seriously reduce yields. Very hard, dry ground makes pulling difficult and increases the number of broken beets. The losses from careless lifting of beets sometimes are as much as 1 ton of beets per acre, or 5 to 10 percent of the crop. A lifter should be so adjusted that it lifts all beets sufficiently to break off the taproot deep in the soil and, at the same time, leaves each beet standing upright so that it is easily handled. Lifters that move the beets sidewise or move them along the row cause many beets to be covered and lost, and, in addition, destroy many of the leaves that are a valuable stock food.

TOPPING

Beets should be piled before they are topped and immediately following lifting. In some districts, the topping is done without piling, the lifted beets being pulled from the soil, the top cut off, and the roots tossed to a pile, the tops falling where cut. Piling prior to

topping has distinct advantage over topping without piling in that less dirt adheres to the roots and the tops are left in a row rather than scattered about the field (fig. 17). Piling is usually done by placing six rows of beets in a pile row with the tops laid outward from an adjacent pile row of six rows of beets. A V-drag is used to smooth a strip of the field between two pile rows of untopped beets; when topped, the beets are placed in the smoothed strip, from which they are easily shoveled into the trucks.

The present sugar-beet contracts require the sugar beets to be topped so that the leaves and crown are removed from the roots by cutting all beets at the base of the lowest leaf scar (fig. 18). Beets under 4 inches in diameter must be cut at a right angle to the long axis of the beet, whereas beets over 4 inches in diameter may be cut at an acute angle to the long axis of the beet, leaving the crown portion as a low

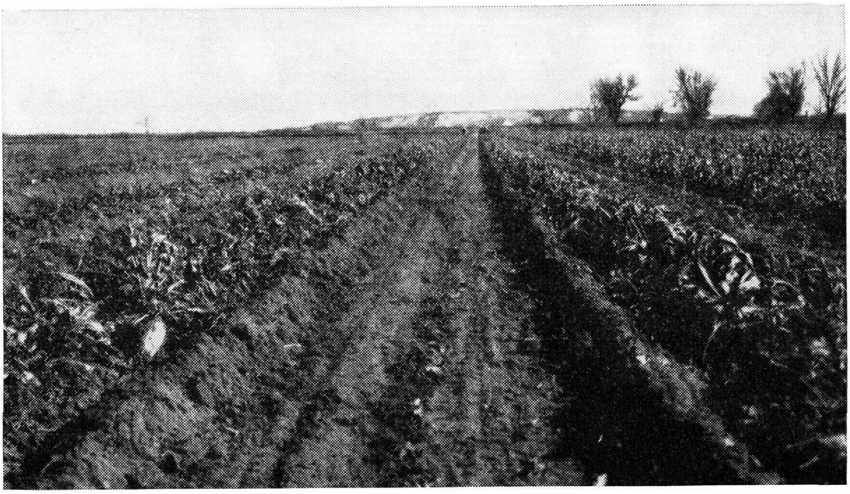

FIGURE 17.—Sugar beets piled preliminary to topping. Six rows have been thrown together and the space between the pile rows smoothed to facilitate loading the topped roots into trucks.

cone. This provision for large roots permits leaving a part of the crown on the root; however, all leaves and outer portions of the crown bearing leaf scars must be removed. Several strokes are required to top a large beet by this method. Unless closely supervised, laborers tend to use only one stroke in topping, regardless of the size of the root. Topping lower than the market requirement decreases the tonnage, and to top higher is useless as the grower receives no payment for the additional crown left on the beet but loses this valuable stock food.

Specially made knives with a hook attached to the point are now generally used in topping beets. The punctures made by the hooks have been shown to serve as starting points for rotting organisms and thus to increase the spoilage of beets in storage. So long as the beets are hand-topped, it is probable that hook injury will continue in spite of the bad effects that come from the wounds made by the hooks. Rather promising development in mechanical harvesters and toppers is being made, and a few are now being used in an experimental way.

DELIVERY

Hauling the beets to the weigh station the same day that they are topped is commonly done. In former years it was not uncommon to see beets lying in the field after they were topped. The increased use of trucks has enabled growers to make more prompt delivery of the beets, and the receiving companies have learned that beets that have been left overnight in the fields are often noticeably damaged either by drying out or freezing. Companies commonly store a portion of the roots in piles from 30 to 60 days before slicing them. Frozen or withered beets do not keep well in storage. In these districts, strict

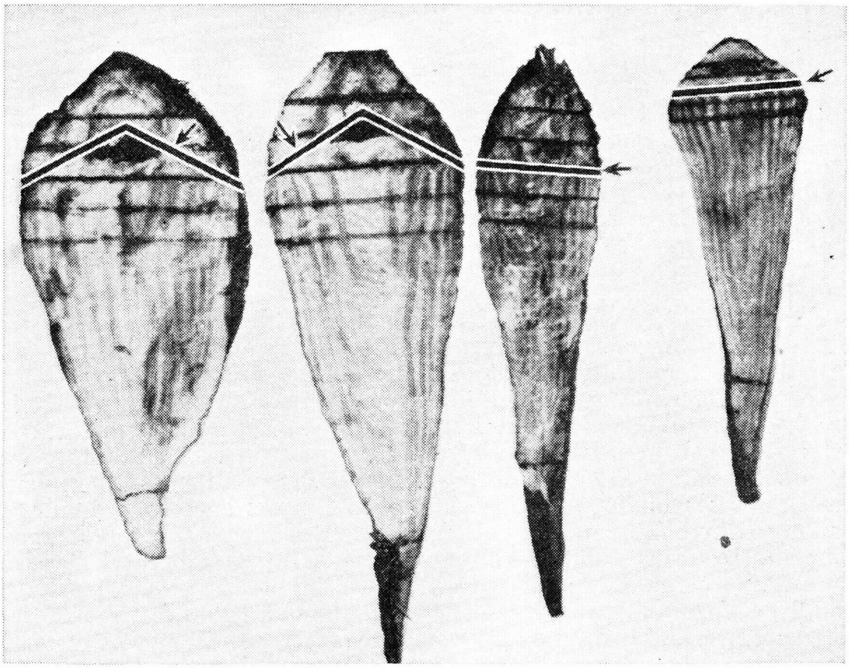

FIGURE 18.—Large, medium, and small sugar-beet roots marked to show different types of topping. The heavy lines indicate the type of topping usually prescribed in the contract.

rules requiring that only fresh beets be delivered are now enforced. It is to the grower's advantage that no frozen beets be delivered to the manufacturers, as the price paid for the beets is directly related to the amount of sugar made. Usually some arrangement is made for direct processing of any loads that have been damaged after topping.

The drying-out of beets in the field is greater than is commonly recognized. During very moist weather, the loss in weight of beets lying in the pile rows may be fairly small, but in the northern Great Plains dry conditions and high winds predominate. The month of October does not normally have 1 inch of rainfall, and over 75 percent of the beets are harvested in October. In this area sugar-beet roots left out in the pile rows ordinarily lose 5 percent of their weight each 24 hours during normal October weather. Covering the beets with tops greatly reduces this loss. More weight is lost if the beets are in

small piles than if the piles are large. Growers do no like to cover the beets with tops because of the labor involved in covering and uncovering the piles, and the beet-sugar companies object when too many leaves are included with the roots, because the presence of leaves frequently interferes with the slicing of the beets and is a factor causing increase of rotting in storage. With the general acceptance of desirability of prompt delivery, growers, as a rule, now load all the beets the day they are topped; some companies cooperate in this move to avoid wastage by keeping receiving stations open after dark to receive beets. When the receiving stations are not kept open, growers are urged to cover the loads with leaves. Some growers have found it profitable to put canvas covers over their loads of beets to prevent frost injury and drying.

An item that needs attention is the rather considerable loss of beets because of overloading of trucks. Because the trucks delivering beets travel at high speed, many beets are lost off the loads on curves or where the roads are rough. Several tons of beets per day can frequently be picked up along a highway. As handling often is done by contract, this waste is preventable by suitable attention on the part of the grower and his contractor.

SUCROSE PERCENTAGE

In the irrigated districts of the northern Great Plains, the sugar beet in the growing season up to the first of September makes a vegetative growth to form a root of moderate size, maximum spread of leaves, and general expansion of its root system. When this stage is reached, the plant is in condition rapidly to accumulate sugar. A relatively high percentage of sugar in comparison with that in other plants is found in the roots during the entire growing season. In general, analyses made prior to September 1 show sucrose percentage usually less than 12 percent, the July and August analyses showing percentages from 8 to 11. At harvesttime, in late October, the sucrose percentage commonly ranges from 15 to 18 percent. Temperature conditions exert a strong influence upon the quantity of sugar stored during the growing period and especially after September 1. As has been mentioned previously, cool fall weather promotes sugar storage, and years of high general sucrose percentages are those in which late September, October, and November have been prevailingly cool. Growers have noticed that late rains or heavy irrigation tends to lower sucrose percentages—a depression in part, at least, attributable to increased intake of water, which increases root weight and correspondingly dilutes the stored substance.

The significance of the green coloring matter of leaves in the manufacture by plants of sugar and carbohydrates is common knowledge. But application of this in its practical aspects is often overlooked in considering the sugar beet as a sugar-manufacturing unit in the field. The important work of leaves is brought to the fore when the effects produced by injury to the leaves are considered. If the foliage is injured, as for example by leaf spot, storage of sugar is affected probably because foliage replacement interferes with storage or draws upon root reserves. Depression of sucrose percentages as much as two units from severe leaf spot injury has been observed. Unless the season is exceptionally prolonged, the loss in sucrose percentage occasioned by

leaf spot attack is seldom made up in the subsequent growth of the plants. In periods in which severe and early fall frosts occur, all or a large part of the leaves are sometimes killed. If warm weather ensues after much frost injury so that leaf growth is stimulated, sucrose percentages sharply decline. Beets upon which the leaves have been killed do not increase much in root weight during the period of formation of new leaves; hence there is no compensating factor for the effect on quality.

The variation in sucrose percentage of individual beets may be due to many causes, including such items as soil differences, heredity, or climatic effects. In other words, the hereditary endowment of the plant and the conditions to which it is exposed, together are reflected in the quality of the root produced. By plant-breeding methods extending over a century, the sugar beet has been bred so that it normally is capable of producing a root in which a very high percentage (15 to 20 percent or more) of its weight is sugar. The varieties used are chiefly the product of mass selection, and the individual plants vary strongly among themselves, the average performance of any commercially acceptable brands or varieties being high, other conditions being favorable. Hence growing conditions as they occur from year to year, among which climatic effects are especially important, are responsible for variation in sucrose percentages.

Growers are often puzzled because there is a spread in the sucrose percentages found in the various load samples. That individual differences exist among the plants and that other conditions within the field vary widely must be recognized. The variations in the sucrose percentages of individual beets make it impossible for sets of analyses of small samples to check closely even though taken from the same field. If analyses of several hundred roots taken at random are compared with a similar sample, the agreement is close.

In the present system of determining sucrose percentages, a small sample is taken from a load; hence, the sucrose percentage found may differ from that obtained for another load. When all are averaged, a close approximation applicable to the totals of deliveries is obtained. The period of delivery of sugar beets extends over a period of 2 to 4 weeks for large fields. Hence, the quality of the beets may change in this period. High or low values, attributable to sampling, tend to counterbalance each other.

The nature of the problem and the variability that may be encountered are illustrated by the following results from analyses made under as close control as possible. It is well recognized that weights of individual beets vary enormously. Ten beets were selected at random from a field where the beets were grown so widely spaced as to be free from competition, to give some idea of the weight differences that may exist among individual beets. The weights in pounds were: 2, 2.2, 2.8, 1.2, 6.5, 0.9, 1.2, 4.1, 6.1, and 2.3. The sucrose percentages found, taking the roots in the same order, were: 12.6, 15.6, 14.0, 14.5, 12.1, 12.9, 13.2, 13.1, 12.5, and 16.6. Other roots, which were grown under conditions of normal competition in a commercial field and which stood adjacent to one another in the row, were selected at random. The weights in pounds found were: 1.5, 3.0, 3.3, 4.3, 2.1, 3.0, 2.7, 2.1, 2.8, and 3.3. The sucrose percentages of these beets, taking them in the order shown for weights, were: 18.7, 17.5, 13.3, 14.6, 12.1, 15.7, 13.8, 16.6, 17.5, and

14.8. The range shown in these analyses, one set representing plants grown so widely spaced that the effect of adjacent plants was avoided and the other under normal field competition, is sufficient to convey a general idea of the variations between individual beets as to both weight and sucrose percentage, even when the individuals compared have been grown under similar conditions. As the number of beets, or the number of samples, increases, the average values obtained become increasingly dependable as applied to the whole lot under consideration. Differences between small individual samples are to be expected and cannot be avoided.

SUGAR-BEET BYPRODUCTS

The byproducts from the sugar-beet crop that are used for stock feeding are beet tops, which are left on the farm, and the factory byproducts, beet pulp, and beet molasses. The high feeding value of sugar-beet byproducts is the basis of an extensive feeding industry in the irrigated areas, which adds definitely to the value of the sugar-beet crop in any district.

SUGAR-BEET TOPS

The leaves and the portion of the crown cut from the beet in harvesting are included under the designation "beet tops." The weight of tops from an acre yield of 12 tons of roots varies from 40 percent to 75 percent or more of the root weight. Yields of tops vary in different fields because of various factors, such as disease or insect attack, maturity of tops at the time of harvest, and soil or growing conditions that have had definite effects on the ratio of root to top weight.

The feeding value of beet tops can conveniently be given in terms of cured tops. Beets are harvested late in the autumn, and the tops do not cure to as dry a state as hay. Moisture percentage usually runs about 30 percent. The weight of cured tops obtained from the average field may be roughly calculated as one-sixth of the weight of the roots. Thus, a crop yielding 12 tons of roots per acre produces approximately 2 tons of cured beet tops. Losses of leaves from poor methods of harvesting or curing are not taken into account in this figure. Many growers waste as much as 25 percent or more of the weight of tops through failure to recover them from the field.

The acre yield of 2 tons of cured tops estimated for the average field contains approximately 1,800 pounds of digestible nutrients. Two tons of alfalfa hay contain approximately 2,000 pounds of digestible nutrients. Hence, it is often said that a ton of cured tops is approximately equal in feed value to a ton of alfalfa. A pound of digestible nutrients can usually be purchased in the form of beet tops for less than it can be purchased in the form of any other stock feed common to the irrigated districts.

Beet tops are fed in several forms and by various methods. Although a very satisfactory method, which gives a high return per acre for the tops, the method of curing and grinding the tops to use as feed to substitute for dried pulp is the least used. In this method, some difficulties are met in curing to a sufficiently dry state to permit grinding, and precaution must be taken to avoid introducing dirt in excess quantity. The hazard that arises from dirt inclusion with any type of handling of beet tops should be recognized.

Pasturing beet tops in the field immediately after harvesting is a method of utilization involving the least labor. This is a good method if the land is dry and the tops are fed in a short time. Curing the tops for 2 or 3 weeks in the pile rows in the fields, followed by further curing in the shock, preliminary to use in feed yards is the most common practice in these irrigated districts (fig. 19). Stacking the cured tops is possible if the tops are dry. The better method is to stack the cured tops in layers about 1 foot thick with a similar layer of either straw or alfalfa hay alternating with the tops. Corn stover and beet tops can be ground together, and by adding water a good silage is made.

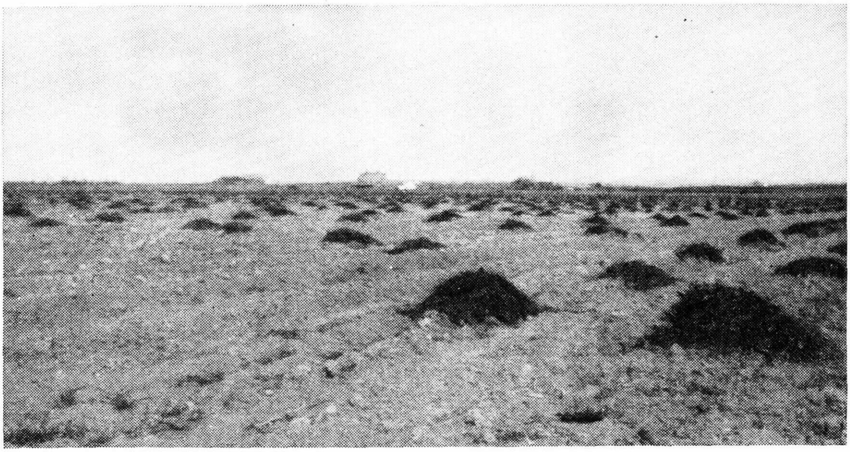

FIGURE 19.—Cured beet tops can be left in the field for several weeks after harvest in the northern Great Plains.

BEET PULP

The residue remaining after the beet roots have been sliced and the sugar extracted by the diffusion process is called beet pulp. The gross weight of pulp obtained is approximately 25 percent of that of the roots sliced. This pulp is used for stock feed in four forms: Fresh, siloed, pressed, or dried. Fresh pulp is high in water content, is bulky to handle, and is used only in limited extent. Siloed pulp is fed for several months following production, the feeding usually being completed by the following summer. Pressed pulp from which a considerable portion of the water has been removed by passing through rollers may be fed direct. It is often siloed after being moved to storage pits near the feed lots. Dried pulp is fed to all types of livestock, either as it comes from the drier or mixed with molasses; it is also mixed with other feeds to make a complete stock food. It can be stored for indefinite periods. Most of the dried pulp is fed in a dry state; however, it can be soaked before feeding.

It is the policy of many beet-sugar companies to encourage the feeding of the greater portion of the pulp produced at a factory in the area where the beets are grown. The livestock-feeding industry is thus fostered and manure production for use on the beet lands increased (figs. 20, 21, 22).

Fresh beet pulp contains approximately 90.5 percent water, 0.4 percent ash, 0.9 percent crude protein, 2.3 percent crude fiber, 5.8

percent nitrogen-free extract, and 0.2 percent ether extract, or fat. Siloed pulp has a higher percentage of dry matter, because the water drains out as the pulp stands in the pits. In general, a pound of dry matter in beet pulp has a feed value equal to a pound of dry matter

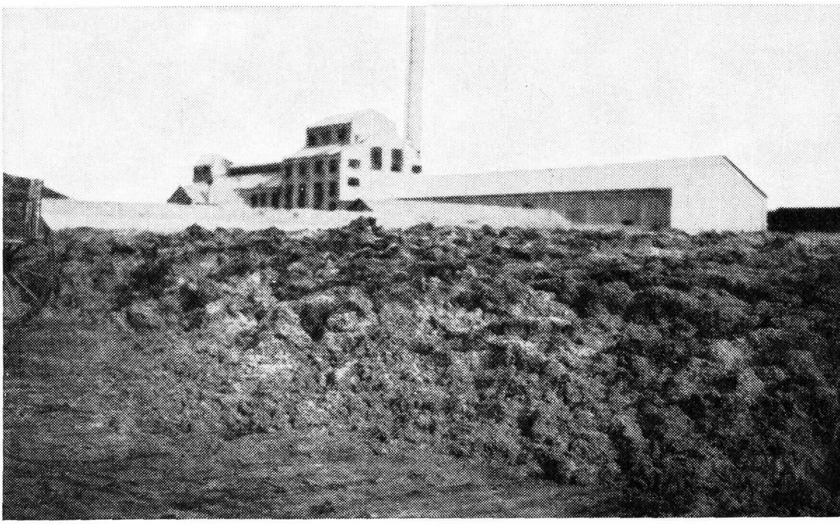

FIGURE 20.—Beet pulp in the beet-sugar-factory storage silo, or floored pit, from which the pulp is hauled to feed livestock.

FIGURE 21.—Trough feeding of siloed sugar-beet pulp to steers.

in grain. Beet pulp is deficient in proteins, phosphates, and calcium, therefore it should be fed in conjunction with legume hay, bonemeal, cottonseed meal, or linseed meal. Recent feeding experiments have shown that where beet pulp and alfalfa hay are fed, bonemeal is a very profitable addition to the ration.

MOLASSES

Sugar-beet molasses contains approximately 59.5 percent of digestible nutrients, 3.5 percent of which are proteins and 56.0 percent are carbohydrates. Molasses contains approximately 5 percent potash salts, which have a laxative effect upon the stock. From 3 to 5 pounds of sugar-beet molasses may be fed per day to each 100 pounds of weight of livestock. Sometimes molasses is fed in a free state, but in most instances it is mixed with other feed such as hay, straw, corn stover, pulp, or beet tops. The palatability of all of the above coarser feeds can be greatly improved by mixing them with molasses, and they are fed with much less waste than if they are fed without molasses. Molasses is so much in demand for feeding that occasionally cane molasses is shipped into the beet-growing area for feed when the local supplies of beet molasses are depleted. Beet molasses may be

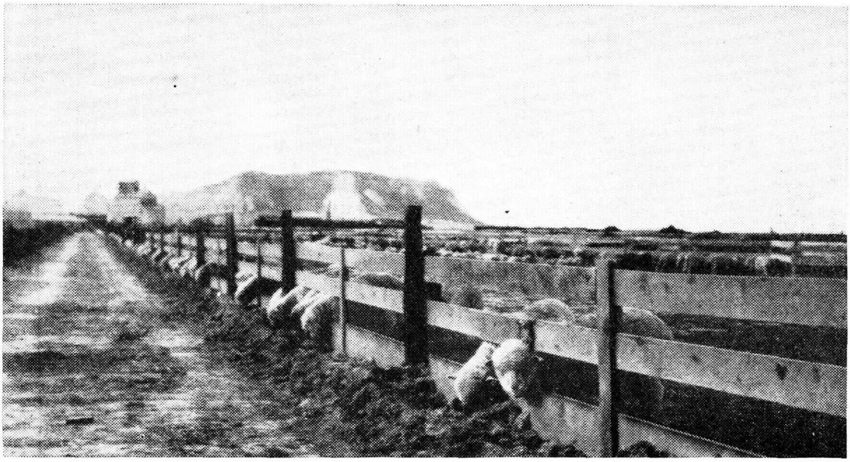

FIGURE 22.—Wet sugar-beet pulp is a good feed for lambs.

used for making alcohol. However, the majority of the beet-sugar manufacturers prefer to sell the molasses for stock feed.

WASTE LIME

A sugar-beet factory slicing 3,000 tons of sugar beets per day uses from 150 to 200 tons of burned limestone per day. In the humid area of the United States and Europe where the soils are acid in reaction, general use is made of the waste lime from the sugar factories for improvement of the soils. Sugar-factory waste lime compares very favorably with agricultural lime in value for use in soil treatment, because it has a calcium-carbonate content of approximately 82 percent. The other ingredients in waste lime are approximately 13 percent organic matter, 0.3 percent nitrogen, 0.5 percent phosphoric acid, and 0.2 percent potash. Almost all of the soils in the irrigated areas are alkaline in reaction and high in calcium content; therefore there has been little use made of the waste lime. Numerous tests of application of waste lime to the soils have been made by growers in these areas, but few marked benefits have been obtained. A few

isolated instances have occurred where the waste lime has been mixed with waste water and washings from the beet flumes and used to fill in low-lying lands adjacent to the factories. This can be done only where the sediments from the factories can be carried to the fields at small expense.

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